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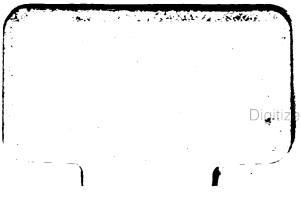
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REPORT

OF THE

TESTS OF METALS

AND

OTHER MATERIALS

MADE WITH THE

UNITED STATES TESTING MACHINE AT WATERTOWN ARSENAL, MASSACHUSETTS, DURING THE FISCAL YEAR ENDED JUNE 30

1913

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

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April 10, 1914
from the
United States Government

WAR DEPARTMENT.

Document No. 404.

Office of the Chief of Ordnance.

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LETTER OF TRANSMITTAL.

WAR DEPARTMENT,
Washington, August 11, 1913.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

SIR: I have the honor to transmit herewith a letter from the Acting Chief of Ordnance, United States Army, dated 9th instant, submitting, for transmission to Congress, as required by law, the report of the commanding officer of Watertown Arsenal of "Tests of iron and steel and other materials for industrial purposes," made at that arsenal during the fiscal year ended June 30, 1913.

Very respectfully,

HENRY BRECKINRIDGE,
Acting Secretary of War.

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LETTER OF SUBMITTAL.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ORDNANCE,
Washington, August 9, 1913.

From: The Ordnance Office.
To: The Secretary of War.
Subject: Annual report, tests of iron, steel, etc., 1913.

I submit herewith, for transmission to Congress, as required by law, the report of the commanding officer of Watertown Arsenal, of "Tests of iron and steel and other materials for industrial purposes," made at that arsenal during the fiscal year ended June 30, 1913.

JNO. T. THOMPSON,
Lieutenant Colonel, Ordnance Department,
Acting Chief of Ordnance.

WATERTOWN ARSENAL,
Watertown, Mass., July 26, 1913.

From: Commanding Officer.
To: The Chief of Ordance, United States Army, Washington, D. C.
Subject: Annual report of tests of metals, etc., for year ending June 30, 1913.

The annual report of tests of iron, steel, and other materials made at this arsenal during the fiscal year ending June 30, 1913, is submitted herewith.

The total number of specimens tested during the year was 3,068, classified as follows:

Gun specimens	29
For Ordance Department	2,281
For other Government departments	56
Tests for private parties	702
Total	3,068

The receipts and expenditures were as follows:

Amount allotted for testing machine and testing work	$14,950.00
Received from private parties	819.62
Total received	15,769.62
Amount expended for services and labor	10,983.05
Amount expended for light, power, tools, implements, and material for test	4,786.57
Total expended	15,769.62

The equipment of the laboratory has been increased by the purchase of the following apparatus:

One Leeds & Northrup thermocouple potentiometer, together with galvanometer.

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One portable resistance measuring outfit.

Three additional eyepieces for Leitz metallographic microscope so that magnifications up to 1,100 diameters can now be taken.

One Hoskins electric muffle furnace.

One Freas constant temperature electric drying oven.

One 8 by 10 inch copying and enlarging camera.

One Meker gas muffle furnace.

One Meker compressed-air crucible furnace.

One Ainsworth analytical balance with multiple rider system.

The tests to determine the relative wearing qualities of bronzes, referred to in the last report, have been continued during the year, and a machine is being designed to secure a more severe test on gears than was obtained in the first test.

Tests of model breech bushings to determine the relative efficiency of cylindrical and conical bushings, and also to determine the relative efficiency of square and V threads have been made.

An investigation of the microstructure of gun forgings now being purchased by the department has been started with the view of securing information on which, as found necessary, changes in the specifications may be based.

Many examinations of the microstructure of metals have been made, principally of steels, and several reports of such examinations by Dr. Henry Fay are included in this report.

C. B. WHEELER,
Lieutenant Colonel, Ordnance Department.

NOTE.—In addition to the receipts and expenditures referred to in the foregoing statement, Rock Island Arsenal was allotted for testing machine and testing work $40.92, and received from private parties $11, making a total of $51.92. This amount was expended for services and labor.

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REPORT

OF THE

TESTS OF METALS

AND

OTHER MATERIALS

MADE WITH THE

UNITED STATES TESTING MACHINE AT WATERTOWN ARSENAL, MASSACHUSETTS, DURING THE FISCAL YEAR ENDED JUNE 30, 1913.

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BREECHBLOCKS FOR 4.7-INCH HOWITZER, MODEL 1912.

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Marks, 1202 F–3.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0003	0.	.00015	.00015	
30,000	.0019	.....	.00095	.00080	30,000 to 60,000 lb. per sq. in.
50,000	.0032	.0003	.00160	.00065	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0036	.....	.00180	.00020	
60,000	.0040	.....	.00200	.00020	
65,000	.0043	.....	.00215	.00015	
66,000	.0044	.....	.00220	.00005	
67,000	.0044	.....	.00220	.00000	
68,000	.0045	.....	.00225	.00005	
69,000	.0045	.....	.00225	.00000	
70,000	.0046	.....	.00230	.00005	
71,000	.0047	.....	.00235	.00005	
72,000	.0048	.....	.00240	.00005	Elastic limit.
73,000	.0050	.....	.00250	.00010	
74,000	.0080	.....	.00400	.00150	
75,000	.0121	.....	.00605	.00205	
76,000	.0145	.....	.00725	.00120	
77,000	.0169	.....	.00845	.00120	
116,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.45 in. in 2 in. = 22.5 per cent.
Elongation of inch sections, 0.11 in., 0.34* in.
Diameter at fracture, 0.35 in.
Sectional area, 0.096 sq. in.
Contraction of area, 51.9 per cent.
Position of fracture, 1 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1188 F–2.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0003	0.	.00015	.00015	
30,000	.0019	.....	.00095	.00080	30,000 to 60,000 lb. per sq. in.
50,000	.0033	0.	.00165	.00070	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0036	.....	.00180	.00015	
60,000	.0040	.....	.00200	.00020	
65,000	.0043	.....	.00215	.00015	
70,000	.0047	.....	.00235	.00020	
71,000	.0048	.....	.00240	.00005	
72,000	.0049	.....	.00245	.00005	
73,000	.0049	.....	.00245	.00000	
74,000	.0050	.....	.00250	.00005	
75,000	.0051	.....	.00255	.00005	
76,000	.0052	.....	.00260	.00005	Elastic limit.
77,000	.0054	.....	.00270	.00010	
78,000	.0056	.....	.00280	.00010	
79,000	.0059	.....	.00295	.00015	
80,000	.0065	.....	.00325	.00030	
81,000	.0075	.....	.00375	.00050	
82,000	.0095	.....	.00475	.00100	
83,000	.0108	.....	.00540	.00065	
116,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.42 in. in 2 in. = 21 per cent.
Elongation of inch sections, 0.30 in., 0.12 in.
Diameter at fracture, 0.35 in.
Sectional area, 0.096 sq. in.
Contraction of area, 51.9 per cent.
Position of fracture, 1.15 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1179 F–2
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	0.	0.	0.	0.	
30,000	.0015	.....	.00075	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0029	0.	.00145	.00070	Modulus of elasticity = 28,930,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00020	
60,000	.0036	.....	.00180	.00015	
65,000	.0040	.....	.00200	.00020	
70,000	.0044	.....	.00220	.00020	
71,000	.0044	.....	.00220	.00000	
72,000	.0045	.....	.00225	.00005	
73,000	.0046	.....	.00230	.00005	
74,000	.0046	.....	.00230	.00000	
75,000	.0047	.....	.00235	.00005	
76,000	.0048	.....	.00240	.00005	
77,000	.0049	.....	.00245	.00005	Elastic limit.
78,000	.0051	.....	.00255	.00010	
79,000	.0055	.....	.00275	.00020	
80,000	.0139	.....	.00695	.00420	
81,000	.0151	.....	.00755	.00060	
82,000	.0169	.....	.00845	.00090	
117,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.44 in. in 2 in. = 22 per cent.
Elongation of inch sections, 0.32* in., 0.12 in.
Diameter at fracture, 0.34 in.
Sectional area, 0.091 sq. in.
Contraction of area, 54.6 per cent.
Position of fracture, 1.16 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

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Marks, 1178 F–2.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0001	0.	.00005	.00005	
30,000	.0015	.....	.00075	.00070	30,000 to 60,000 lb. per sq. in.
50,000	.0028	—.0003	.00140	.00065	Modulus of elasticity=31,580,000 lb. per sq. in.
55,000	.0030	.....	.00150	.00010	
60,000	.0034	.....	.00170	.00020	
65,000	.0036	.....	.00180	.00010	
70,000	.0041	.....	.00205	.00025	
71,000	.0041	.....	.00205	.00000	
72,000	.0042	.....	.00210	.00005	
73,000	.0043	.....	.00215	.00005	
74,000	.0044	.....	.00220	.00005	
75,000	.0045	.....	.00225	.00005	Elastic limit.
76,000	.0047	.....	.00235	.00010	
77,000	.0051	.....	.00255	.00020	
78,000	.0056	.....	.00280	.00025	
79,000	.0066	.....	.00330	.00050	
80,000	.0081	.....	.00405	.00075	
81,000	.0099	.....	.00495	.00090	
82,000	.0119	.....	.00595	.00100	
113,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.42 in. in 2 in. = 21 per cent.
Elongation of inch sections, 0.20* in., 0.22* in.
Diameter at fracture, 0.36 in.
Sectional area, 0.102 sq. in.
Contraction of area, 49.1 per cent.
Position of fracture, 1.25 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1177 F–2.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0001	0.	.00005	.00005	
30,000	.0014	.....	.00070	.00065	30,000 to 60,000 lb. per sq. in.
50,000	.0027	0.	.00135	.00065	Modulus of elasticity=31,580,000 lb. per sq. in.
55,000	.0029	.....	.00145	.00010	
60,000	.0033	.....	.00165	.00020	
65,000	.0036	.....	.00180	.00015	
70,000	.0040	.....	.00200	.00020	
71,000	.0041	.....	.00205	.00005	
72,000	.0042	.....	.00210	.00005	
73,000	.0043	.....	.00215	.00005	
74,000	.0044	.....	.00220	.00005	
75,000	.0044	.....	.00220	.00000	
76,000	.0045	.....	.00225	.00005	
77,000	.0046	.....	.00230	.00005	Elastic limit.
78,000	.0048	.....	.00240	.00010	
79,000	.0050	.....	.00250	.00010	
80,000	.0052	.....	.00260	.00010	
81,000	.0056	.....	.00280	.00020	
82,000	.0064	.....	.00320	.00040	
83,000	.0074	.....	.00370	.00050	
84,000	.0089	.....	.00445	.00075	
85,000	.0106	.....	.00530	.00085	
118,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.38 in. in 2 in. = 19 per cent.
Elongation of inch sections, 0.25* in., 0.13 in.
Diameter at fracture, 0.37 in.
Sectional area, 0.108 sq. in.
Contraction of area, 46.2 per cent.
Position of fracture, 1.20 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1199–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	.0001	.00010	.00010	
30,000	.0015	.....	.00075	.00065	30,000 to 60,000 lb. per sq. in.
50,000	.0027	0.	.00135	.00060	Modulus of elasticity=30,000,000 lb. per sq. in.
55,000	.0032	.....	.00160	.00025	
60,000	.0035	.....	.00175	.00015	
61,000	.0036	.....	.00180	.00005	
62,000	.0037	.....	.00185	.00005	
63,000	.0038	.....	.00190	.00005	
64,000	.0039	.....	.00195	.00005	
65,000	.0040	.....	.00200	.00005	Elastic limit.
66,000	.0043	.....	.00215	.00015	
67,000	.0047	.....	.00235	.00020	
68,000	.0070	.....	.00350	.00115	
69,000	.0124	.....	.00620	.00270	
70,000	.0146	.....	.00730	.00110	
108,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.47 in. in 2 in. = 23.5 per cent.
Elongation of inch sections, 0.14 in., 0.33* in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 1.08 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

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Marks, 1195–F.
Diameter, 0.506 in.
Sectional area, 0.201 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	−.0001	.0002	−.00005	−.00005	
30,000	.0014	.....	.00070	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0028	0.	.00140	.00070	Modulus of elasticity=28,930,000 lb.
55,000	.0032	.....	.00160	.00020	per sq. in.
60,000	.0035	.....	.00175	.00015	
61,000	.0036	.....	.00180	.00005	
62,000	.0037	.....	.00185	.00005	
63,000	.0038	.....	.00190	.00005	
64,000	.0039	.....	.00195	.00005	
65,000	.0040	.....	.00200	.00005	
66,000	.0041	.....	.00205	.00005	
67,000	.0042	.....	.00210	.00005	Elastic limit.
68,000	.0044	.....	.00220	.00010	
69,000	.0046	.....	.00230	.00010	
70,000	.0054	.....	.00270	.00040	
71,000	.0084	.....	.00420	.00150	
72,000	.0120	.....	.00600	.00180	
106,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.47 in. in 2 in. = 23.5 per cent.
Elongation of inch sections, 0.23 in., 0.24* in.
Diameter at fracture, 0.35 in.
Sectional area, 0.096 sq. in.
Contraction of area, 51.9 per cent.
Position of fracture, 1.25 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1190–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0015	.....	.00075	.00065	30,000 to 60,000 lb. per sq. in.
50,000	.0029	0.	.00145	.00070	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00020	
60,000	.0036	.....	.00180	.00015	
61,000	.0037	.....	.00185	.00005	
62,000	.0038	.....	.00190	.00005	
63,000	.0039	.....	.00195	.00005	
64,000	.0040	.....	.00200	.00005	
65,000	.0041	.....	.00205	.00005	Elastic limit.
66,000	.0043	.....	.00215	.00010	
67,000	.0046	.....	.00230	.00015	
68,000	.0050	.....	.00250	.00020	
69,000	.0063	.....	.00315	.00065	
70,000	.0134	.....	.00670	.00355	
109,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.46 in. in 2 in. = 23 per cent.
Elongation of inch sections, 0.11 in., 0.35* in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 0.82 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1196–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0003	0.	.00015	.00015	
30,000	.0020	.....	.00100	.00085	30,000 to 60,000 lb. per sq. in.
50,000	.0034	0.	.00170	.00070	Modulus of elasticity=27,270,000 lb. per sq. in.
55,000	.0038	.....	.00190	.00020	
60,000	.0042	.....	.00210	.00020	
61,000	.0043	.....	.00215	.00005	
62,000	.0044	.....	.00220	.00005	
63,000	.0045	.....	.00225	.00005	
64,000	.0046	.....	.00230	.00005	Elastic limit.
65,000	.0049	.....	.00245	.00015	
66,000	.0063	.....	.00315	.00070	
67,000	.0123	.....	.00615	.00300	
68,000	.0144	.....	.00720	.00105	
69,000	.0165	.....	.00825	.00105	
70,000	.0184	.....	.00920	.00095	
106,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.48 in. in 2 in. = 24 per cent.
Elongation of inch sections, 0.12 in., 0.36* in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 0.96 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

Digitized by Google

Marks, 1184–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0018	.....	.00090	.00080	30,000 to 60,000 lb. per sq. in.
50,000	.0031	0.	.00155	.00065	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0035	.....	.00175	.00020	
60,000	.0039	.....	.00195	.00020	
61,000	.0039	.....	.00195	.00000	
62,000	.0040	.....	.00200	.00005	
63,000	.0041	.....	.00205	.00005	
64,000	.0042	.....	.00210	.00005	
65,000	.0043	.....	.00215	.00005	
66,000	.0044	.....	.00220	.00005	
67,000	.0045	.....	.00225	.00005	Elastic limit.
68,000	.0060	.....	.00300	.00075	
69,000	.0129	.....	.00645	.00345	
70,000	.0151	.....	.00755	.00120	
71,000	.0171	.....	.00855	.00100	
107,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.48 in. in 2 in. = 24 per cent.
Elongation of inch sections, 0.12 in., 0.36* in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 0.90 in. from the neck.
Appearance of fracture, fine silky.

Digitized by Google

Marks, 1183–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0018	.....	.00090	.00080	30,000 to 60,000 lb. per sq. in.
50,000	.0030	0.	.00150	.00060	Modulus of elasticity=31,580,000 lb. per sq. in.
55,000	.0034	.....	.00170	.00020	
60,000	.0037	.....	.00185	.00015	
61,000	.0037	.....	.00185	.00000	
62,000	.0038	.....	.00190	.00005	
63,000	.0039	.....	.00195	.00005	
64,000	.0040	.....	.00200	.00005	
65,000	.0041	.....	.00205	.00005	
66,000	.0042	.....	.00210	.00005	
67,000	.0043	.....	.00215	.00005	Elastic limit.
68,000	.0124	.....	.00620	.00405	
69,060	.0212	.....	.01060	.00440	
70,000	.0230	.....	.01150	.00090	
71,000	.0246	.....	.01230	.00080	
104,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.53 in. in 2 in. = 26.5 per cent.
Elongation of inch sections, 0.37* in., 0.16 in.
Diameter at fracture, 0.31 in.
Sectional area, 0.075 sq. in.
Contraction of area, 62.3 per cent.
Position of fracture, 1.15 in. from the neck.
Appearance of fracture, fine silky, serrated.

Digitized by Google

Marks, 1180–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0003	0.	.00015	.00015	
30,000	.0021	.....	.00105	.00090	30,000 to 60,000 lb. per sq. in.
50,000	.0035	0.	.00175	.00070	Modulus of elasticity=28,930,000 lb.
55,000	.0038	.....	.00190	.00015	per sq. in.
56,000	.0039	.....	.00195	.00005	
57,000	.0039	.....	.00195	.00000	
58,000	.0040	.....	.00200	.00005	
59,000	.0041	.....	.00205	.00005	
60,000	.0042	.....	.00210	.00005	
61,000	.0043	.....	.00215	.00005	
62,000	.0044	.....	.00220	.00005	Elastic limit.
63,000	.0046	.....	.00230	.00010	
64,000	.0050	.....	.00250	.00020	
65,000	.0056	.....	.00280	.00030	
66,000	.0111	.....	.00555	.00275	
67,000	.0136	.....	.00680	.00125	
106,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.50 in. in 2 in. = 25 per cent.
Elongation of inch sections, 0.36* in., 0.14 in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 1.18 in. from the neck.
Appearance of fracture, fine silky.

Digitized by Google

Marks, 1179–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0019	.....	.00095	.00085	30,000 to 60,000 lb. per sq. in.
50,000	.0033	0.	.00165	.00075	Modulus of elasticity=30,000,000 lb. per sq. in.
55,000	.0036	.....	.00180	.00015	
60,000	.0039	.....	.00195	.00015	
61,000	.0040	.....	.00200	.00005	
62,000	.0041	.....	.00205	.00005	
63,000	.0042	.....	.00210	.00005	
64,000	.0043	.....	.00215	.00005	
65,000	.0043	.....	.00215	.00000	Elastic limit.
66,000	.0132	.....	.00660	.00445	
67,000	.0162	.....	.00810	.00150	
68,000	.0183	.....	.00915	.00105	
69,000	.0198	.....	.00990	.00075	
105,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.51 in. in 2 in. = 25.5 per cent.
Elongation of inch sections, 0.14 in., 0.37* in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.07 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

Digitized by Google

Marks, 1178–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0016	.....	.00080	.00070	30,000 to 60,000 lb. per sq. in.
50,000	.0030	0.	.00150	.00070	Modulus of elasticity=30,000,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00015	
60,000	.0036	.....	.00180	.00015	
61,000	.0037	.....	.00185	.00005	
62,000	.0038	.....	.00190	.00005	
63,000	.0039	.....	.00195	.00005	
64,000	.0040	.....	.00200	.00005	
65,000	.0041	.....	.00205	.00005	
66,000	.0042	.....	.00210	.00005	Elastic limit.
67,000	.0044	.....	.00220	.00010	
68,000	.0053	.....	.00265	.00045	
69,000	.0084	.....	.00420	.00155	
70,000	.0112	.....	.00560	.00140	
71,000	.0136	.....	.00680	.00120	
108,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.45 in. in 2 in. = 22.5 per cent.
Elongation of inch sections, 0.10 in., 0.35* in.
Diameter at fracture, 0.34 in.
Sectional area, 0.091 sq. in.
Contraction of area, 54.6 per cent.
Position of fracture, 0.80 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

Digitized by Google

Marks, 1201–F.
Diameter, 0.502 in.
Sectional area, 0.198 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0003	0.	.00015	.00015	
30,000	.0022	.....	.00110	.00095	30,000 to 60,000 lb. per sq. in.
50,000	.0037	0.	.00185	.00075	Modulus of elasticity=26,080,000 lb. per sq. in.
55,000	.0041	.....	.00205	.00020	
60,000	.0045	.....	.00225	.00020	
61,000	.0046	.....	.00230	.00005	
62,000	.0047	.....	.00235	.00005	
63,000	.0048	.....	.00240	.00005	Elastic limit.
64,000	.0050	.....	.00250	.00010	
65,000	.0053	.....	.00265	.00015	
66,000	.0059	.....	.00295	.00030	
67,000	.0075	.....	.00375	.00080	
68,000	.0121	.....	.00605	.00235	
69,000	.0165	.....	.00825	.00220	
107,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.50 in. in 2 in. = 25 per cent.
Elongation of inch sections, 0.18 in., 0.32* in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 1.25 in. from the neck.
Appearance of fracture, fine silky.

Digitized by Google

Marks, 1194–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0017	.....	.00085	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0033	0.	.00165	.00080	Modulus of elasticity=26,060,000 lb. per sq. in.
55,000	.0037	.....	.00185	.00020	
60,000	.0040	.....	.00200	.00015	
61,000	.0041	.....	.00205	.00005	
62,000	.0042	.....	.00210	.00005	
63,000	.0042	.....	.00210	.00000	
64,000	.0043	.....	.00215	.00005	
65,000	.0044	.....	.00220	.00005	Elastic limit.
66,000	.0046	.....	.00230	.00010	
67,000	.0048	.....	.00240	.00010	
68,000	.0053	.....	.00265	.00020	
69,000	.0068	.....	.00340	.00075	
70,000	.0102	.....	.00510	.00170	
71,000	.0134	.....	.00670	.00160	
108,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.43 in. in 2 in. = 21.5 per cent.
Elongation of inch sections, 0.09 in., 0.34* in.
Diameter at fracture, 0.34 in.
Sectional area, 0.091 sq. in.
Contraction of areas, 54.6 per cent.
Position of fracture, 0.78 in. from the neck.
Appearance of fracture, fine silky.

Digitized by Google

Marks, 1193–F.
Diameter, 0.503 in.
Sectional area, 0.199 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0016	.....	.00080	.00070	30,000 to 60,000 lb. per sq. in.
50,000	.0029	0.	.00145	.00065	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00020	
60,000	.0037	.....	.00185	.00020	
61,000	.0038	.....	.00190	.00005	
62,000	.0039	.....	.00195	.00005	
63,000	.0040	.....	.00200	.00005	
64,000	.0041	.....	.00205	.00005	Elastic limit.
65,000	.0043	.....	.00215	.00010	
66,000	.0045	.....	.00225	.00010	
67,000	.0049	.....	.00245	.00020	
68,000	.0054	.....	.00270	.00025	
69,000	.0079	.....	.00395	.00125	
70,000	.0113	.....	.00565	.00170	
108,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.45 in. in 2 in. = 22.5 per cent.
Elongation of inch sections, 0.34* in., 0.11 in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 0.80 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

Digitized by Google

Marks, 1188–F.
Diameter, 0.502 in.
Sectional area, 0.198 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0017	.....	.00085	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0031	0.	.00155	.00075	Modulus of elasticity=27,270,000 lb. per sq. in.
55,000	.0035	.....	.00175	.00020	
60,000	.0039	.....	.00195	.00020	
61,000	.0040	.....	.00200	.00005	Elastic limit.
62,000	.0042	.....	.00210	.00010	
63,000	.0044	.....	.00220	.00010	
64,000	.0048	.....	.00240	.00020	
65,000	.0056	.....	.00280	.00040	
66,000	.0095	.....	.00475	.00195	
67,000	.0155	.....	.00775	.00300	
68,000	.0171	.....	.00855	.00080	
105,600	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.50 in. in 2 in. = 25 per cent.
Elongation of inch sections, 0.39* in., 0.11 in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.02 in. from the neck.
Appearance of fracture, fine silky.

Digitized by Google

Marks, 1187–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0001	0.	.00005	.00005	
30,000	.0016	.....	.00080	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0029	0.	.00145	.00065	Modulus of elasticity=30,000,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00020	
60,000	.0036	.....	.00180	.00015	
61,000	.0037	.....	.00185	.00005	
62,000	.0037	.....	.00185	.00000	
63,000	.0038	.....	.00190	.00005	
64,000	.0039	.....	.00195	.00005	Elastic limit.
65,000	.0042	.....	.00210	.00015	
66,000	.0050	.....	.00250	.00040	
67,000	.0104	.....	.00520	.00270	
68,000	.0151	.....	.00755	.00235	
69,000	.0167	.....	.00835	.00080	
70,000	.0185	.....	.00925	.00090	
106,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.50 in. in 2 in. = 25 per cent.
Elongation of inch sections, 0.15 in., 0.35* in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.13 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

Digitized by Google

Marks, 1204–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0019	.....	.00090	.00080	30,000 to 60,000 lb. per sq. in.
50,000	.0033	0.	.00165	.00075	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0036	.....	.00180	.00015	
60,000	.0039	.....	.00195	.00015	
61,000	.0039	.....	.00195	.00000	
62,000	.0040	.....	.00200	.00005	
63,000	.0041	.....	.00205	.00005	
64,000	.0041	.....	.00205	.00000	
65,000	.0042	.....	.00210	.00005	
66,000	.0043	.....	.00215	.00005	
67,000	.0044	.....	.00220	.00005	Elastic limit.
68,000	.0056	.....	.00280	.00060	
69,000	.0125	.....	.00625	.00345	
70,000	.0156	.....	.00780	.00155	
71,000	.0162	.....	.00810	.00030	
108,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.46 in. in 2 in. = 23 per cent.
Elongation of inch sections, 0.36* in., 0.10 in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 0.74 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

Digitized by Google

Marks, 1203–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0019	.....	.00095	.00085	30,000 to 60,000 lb. per sq. in.
50,000	.0033	0.	.00165	.00070	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0037	.....	.00185	.00020	
60,000	.0040	.....	.00200	.00015	
61,000	.0041	.....	.00205	.00005	
62,000	.0042	.....	.00210	.00005	
63,000	.0043	.....	.00215	.00005	
64,000	.0044	.....	.00220	.00005	
65,000	.0045	.....	.00225	.00005	
66,000	.0046	.....	.00230	.00005	Elastic limit.
67,000	.0056	.....	.00280	.00050	
68,000	.0117	.....	.00585	.00305	
69,000	.0160	.....	.00800	.00215	
70,000	.0173	.....	.00865	.00065	
107,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.50 in. in 2 in. = 25 per cent.
Elongation of inch sections, 0.33* in., 0.17 in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.20 in. from the neck.
Appearance of fracture, fine silky.

Digitized by Google

Marks, 1198–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0017	.....	.00085	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0030	0.	.00150	.00065	Modulus of elasticity=31,580,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00015	
60,000	.0036	.....	.00180	.00015	
61,000	.0037	.....	.00185	.00005	
62,000	.0037	.....	.00185	.00000	
63,000	.0038	.....	.00190	.00005	
64,000	.0039	.....	.00195	.00005	
65,000	.0040	.....	.00200	.00005	
66,000	.0041	.....	.00205	.00005	
67,000	.0042	.....	.00210	.00005	
68,000	.0042	.....	.00210	.00000	Elastic limit.
69,000	.0056	.....	.00280	.00070	
70,000	.0113	.....	.00565	.00285	
71,000	.0135	.....	.00675	.00110	
72,000	.0155	.....	.00775	.00100	
109,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.48 in. in 2 in. = 24 per cent.
Elongation of inch sections, 0.33* in., 0.15 in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.20 in. from the neck.
Appearance of fracture, fine silky.

Digitized by Google

Marks, 1197–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0001	0.	.00005	.00005	
30,000	.0016	.....	.00080	.00075	30,000 to 60,000 lb. per sq in.
50,000	.0030	0.	.00150	.00070	Modulus of elasticity=30,000,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00015	
60,000	.0036	.....	.00180	.00015	
61,000	.0037	.....	.00185	.00005	
62,000	.0038	.....	.00190	.00005	
63,000	.0038	.....	.00190	.00000	
64,000	.0039	.....	.00195	.00005	
65,000	.0040	.....	.00200	.00005	
66,000	.0041	.....	.00205	.00005	Elastic limit.
67,000	.0045	.....	.00225	.00020	
68,000	.0053	.....	.00265	.00040	
69,000	.0088	.....	.00440	.00175	
70,000	.0167	.....	.00835	.00395	
108,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.51 in. in 2 in. = 25.5 per cent.
Elongation of inch sections, 0.20 in., 0.31* in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.20 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1192–F.
Diameter, 0.502 in.
Sectional area, 0.198 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0019	.....	.00095	.00085	30,000 to 60,000 lb. per sq. in.
50,000	.0033	0.	.00165	.00070	Modulus of elasticity=30,000,000 lb.
55,000	.0036	.....	.00180	.00015	per sq. in.
60,000	.0039	.....	.00195	.00015	
61,000	.0039	.....	.00195	.00000	
62,000	.0040	.....	.00200	.00005	
63,000	.0041	.....	.00205	.00005	
64,000	.0042	.....	.00210	.00005	Elastic limit.
65,000	.0044	.....	.00220	.00010	
66,000	.0050	.....	.00250	.00030	
67,000	.0079	.....	.00395	.00145	
68,000	.0118	.....	.00590	.00195	
69,000	.0141	.....	.00705	.00115	
70,000	.0164	.....	.00820	.00115	
107,100	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.48 in. in 2 in. = 24 per cent.
Elongation of inch sections, 0.12 in., 0.36* in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 56.6 per cent.
Position of fracture, 0.92 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

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Marks, 1191–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0003	0.	.00015	.00015	
30,000	.0018	.....	.00090	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0031	0.	.00155	.00065	Modulus of elasticity=30,000,000 lb. per sq. in.
55,000	.0034	.....	.00170	.00025	
60,000	.0038	.....	.00190	.00020	
61,000	.0039	.....	.00195	.00005	
62,000	.0040	.....	.00200	.00005	
63,000	.0040	.....	.00200	.00000	
64,000	.0041	.....	.00205	.00005	
65,000	.0042	.....	.00210	.00005	Elastic limit.
66,000	.0044	.....	.00220	.00010	
67,000	.0050	.....	.00250	.00030	
68,000	.0068	.....	.00340	.00090	
69,000	.0113	.....	.00565	.00225	
70,000	.0134	.....	.00670	.00105	
108,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.46 in. in 2 in. =23 per cent.
Elongation of inch sections, 0.13, 0.33* in.
Diameter at fracture, 0.34 in.
Sectional area, 0.091 sq. in.
Contraction of area, 54.6 per cent.
Position of fracture, 1 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1186–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0016	.....	.00080	.00070	30,000 to 60,000 lb. per sq. in.
50,000	.0029	0.	.00145	.00065	Modulus of elasticity=30,000,000 lb. per sq. in.
55,000	.0033	.....	.00165	.00020	
60,000	.0036	.....	.00180	.00015	
61,000	.0037	.....	.00185	.00005	
62,000	.0038	.....	.00190	.00005	
63,000	.0039	.....	.00195	.00005	
64,000	.0040	.....	.00200	.00005	
65,000	.0041	.....	.00205	.00005	
66,000	.0042	.....	.00210	.00005	Elastic limit.
67,000	.0044	.....	.00220	.00010	
68,000	.0054	.....	.00270	.00050	
69,000	.0069	.....	.00345	.00075	
70,000	.0096	.....	.00480	.00135	
71,000	.0133	.....	.00665	.00185	
108,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.44 in. in 2 in. = 22 per cent.
Elongation of inch sections, 0.09 in., 0.35* in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 0.75 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1185–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0017	.....	.00085	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0031	0.	.00155	.00075	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0035	.....	.00175	.00020	
60,000	.0038	.....	.00190	.00015	
61,000	.0039	.....	.00195	.00005	
62,000	.0040	.....	.00200	.00005	
63,000	.0041	.....	.00205	.00005	
64,000	.0041	.....	.00205	.00000	
65,000	.0042	.....	.00210	.00005	
66,000	.0043	.....	.00215	.00005	
67,000	.0044	.....	.00220	.00005	
68,000	.0045	.....	.00225	.00005	Elastic limit.
69,000	.0097	.....	.00485	.00260	
70,000	.0170	.....	.00850	.00365	
71,000	.0200	.....	.01000	.00150	
106,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.51 in. in 2 in.=25.5 per cent.
Elongation of inch sections, 0.14 in., 0.37* in.
Diameter at fracture, 0.32 in.
Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.02 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1182–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0015	.....	.00075	.00065	30,000 to 60,000 lb. per sq. in.
50,000	.0027	0.	.00135	.00065	Modulus of elasticity=30,000,000 lb.
55,000	.0032	.....	.00160	.00025	per sq. in.
60,000	.0035	.....	.00175	.00015	
61,000	.0036	.....	.00180	.00005	
62,000	.0037	.....	.00185	.00005	
63,000	.0038	.....	.00190	.00005	
64,000	.0039	.....	.00195	.00005	Elastic limit.
65,000	.0041	.....	.00205	.00010	
66,000	.0050	.....	.00250	.00045	
67,000	.0061	.....	.00305	.00055	
68,000	.0110	.....	.00550	.00245	
69,000	.0134	.....	.00670	.00120	
70,000	.0154	.....	.00770	.00100	
108,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.49 in. in 2 in. = 24.5 per cent.
Elongation of inch sections, 0.36* in., 0.13 in.
Diameter at fracture, 0.34 in.
Sectional area, 0.091 sq. in.
Contraction of area, 54.6 per cent.
Position of fracture, 1.10 in. from the neck.
Appearance of fracture, fine silky, cup shaped.

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Marks, 1181–F.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0004	0.	.00020	.00020	
30,000	.0024	.....	.00120	.00100	30,000 to 60,000 lb. per sq. in.
50,000	.0039	.0002	.00195	.00075	Modulus of elasticity=28,930,000 lb.
55,000	.0042	.....	.00210	.00015	per sq. in.
60,000	.0045	.....	.00225	.00015	
61,000	.0046	.....	.00230	.00005	
62,000	.0047	.....	.00235	.00005	
63,000	.0048	.....	.00240	.00005	
64,000	.0049	.....	.00245	.00005	
65,000	.0050	.....	.00250	.00005	Elastic limit.
66,000	.0052	.....	.00260	.00005	
67,000	.0055	.....	.00275	.00015	
68,000	.0060	.....	.00300	.00025	
69,000	.0069	.....	.00345	.00045	
70,000	.0120	.....	.00600	.00255	
71,000	.0145	.....	.00725	.00125	
110,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.46 in. in 2 in. = 23 per cent.
Elongation of inch sections, 0.12 in., 0.34* in.
Diameter at fracture, 0.33 in.
Sectional area, 0.086 sq. in.
Contraction of area, 57.2 per cent.
Position of fracture, 0.90 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1200 F T.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0016	.....	.00080	.00070	30,000 to 60,000 lb. per sq. in.
50,000	.0030	0.	.00150	.00030	Modulus of elasticity=26,080,000 lb per sq. in.
55,000	.0035	.....	.00175	.00025	
60,000	.0039	.....	.00195	.00020	
61,000	.0040	.....	.00200	.00005	
62,000	.0041	.....	.00205	.00005	
63,000	.0042	.....	.00210	.00005	
64,000	.0042	.....	.00210	.00000	
65,000	.0043	.....	.00215	.00005	
66,000	.0044	.....	.00220	.00005	Elastic limit.
67,000	.0069	.....	.00345	.00125	
68,000	.0130	.....	.00650	.00305	
69,000	.0174	.....	.00870	.00220	
70,000	.0195	.....	.00975	.00105	
105,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.36 in. in 2 in. = 18 per cent.
Elongation of inch sections, 0.24* in., 0.12 in.
Diameter at fracture, 0.43 in.
Sectional area, 0.145 sq. in.
Contraction of area, 27.4 per cent.
Position of fracture, 1.04 in. from the neck.
Appearance of fracture, fine granular, 30 per cent; lamellar, 70 per cent.

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Marks, 1200 F L.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0017	.....	.00085	.00075	30,000 to 60,000 lb. per sq. in.
50,000	.0030	0.	.00150	.00065	Modulus of elasticity=31,580,000 lb.
55,000	.0033	.....	.00165	.00015	per sq. in.
60,000	.0036	.....	.00180	.00015	
61,000	.0037	.....	.00185	.00005	
62,000	.0038	.....	.00190	.00005	
63,000	.0039	.....	.00195	.00005	
64,000	.0039	.....	.00195	.00000	
65,000	.0040	.....	.00200	.00005	
66,000	.0041	.....	.00205	.00005	Elastic limit.
67,000	.0183	.....	.00915	.00710	
68,000	.0204	.....	.01020	.00105	
69,000	.0212	.....	.01060	.00040	
70,000	.0229	.....	.01145	.00085	
105,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.51 in. in 2 in. = 25.5 per cent.
Elongation of inch sections, 0.13, 0.38* in.
Diameter of fracture, 0.32 in. Sectional area, 0.080 sq. in.
Contraction of area, 59.8 per cent.
Position of fracture, 1.01 in. from the neck.
Appearance of fracture, fine silky.

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Marks, 1189 F T.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0002	0.	.00010	.00010	
30,000	.0018	.....	.00090	.00080	30,000 to 60,000 lb. per sq. in.
50,000	.0033	0.	.00165	.00075	Modulus of elasticity=26,080,000 lb. per sq. in.
55,000	.0038	.....	.00190	.00025	
60,000	.0041	.....	.00205	.00015	
61,000	.0041	.....	.00205	.00000	
62,000	.0042	.....	.00210	.00005	
63,000	.0043	.....	.00215	.00005	
64,000	.0044	.....	.00220	.00005	Elastic limit.
65,000	.0046	.....	.00230	.00010	
66,000	.0056	.....	.00280	.00050	
67,000	.0065	.....	.00325	.00045	
68,000	.0089	.....	.00445	.00120	
69,000	.0115	.....	.00575	.00130	
70,000	.0140	.....	.00700	.00125	
107,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.34 in. in 2 in. = 17 per cent.
Elongation of inch sections, 0.13, 0.21* in.
Diameter of fracture, 0.43 in. Sectional area, 0.145 sq. in.
Contraction of area, 27.4 per cent.
Position of fracture, 1.16 in. from the neck.
Appearance of fracture, fine granular, 60 per cent; lamellar, 40 per cent.

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TEST 414.

Marks, 1189 F L.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Applied loads per square inch.	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
Lb.	*In.*	*In.*	*In.*	*In.*	
1,000	0.	0.	0.	0.	Initial load.
5,000	.0003	0.	.00015	.00015	
30,000	.0020	.....	.00100	.00085	30,000 to 60,000 lb. per sq. in.
50,000	.0034	0.	.00170	.00070	Modulus of elasticity=28,930,000 lb. per sq. in.
55,000	.0037	.....	.00185	.00015	
60,000	.0041	.....	.00205	.00020	
61,000	.0042	.....	.00210	.00005	
62,000	.0043	.....	.00215	.00005	
63,000	.0044	.....	.00220	.00005	
64,000	.0045	.....	.00225	.00005	
65,000	.0046	.....	.00230	.00005	Elastic limit.
66,000	.0048	.....	.00240	.00010	
67,000	.0057	.....	.00285	.00045	
68,000	.0088	.....	.00440	.00155	
69,000	.0124	.....	.00620	.00180	
70,000	.0149	.....	.00745	.00125	
108,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.57 in. in 2 in. = 28.5 per cent.
Elongation of inch sections, 0.33* in., 0.24 in.
Diameter at fracture, 0.34 in. Sectional area, 0.091 sq. in.
Contraction of area, 54.6 per cent.
Position of fracture, 1.05 in. from the neck.
Appearance of fracture, fine silky.

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STEEL COLUMNS.

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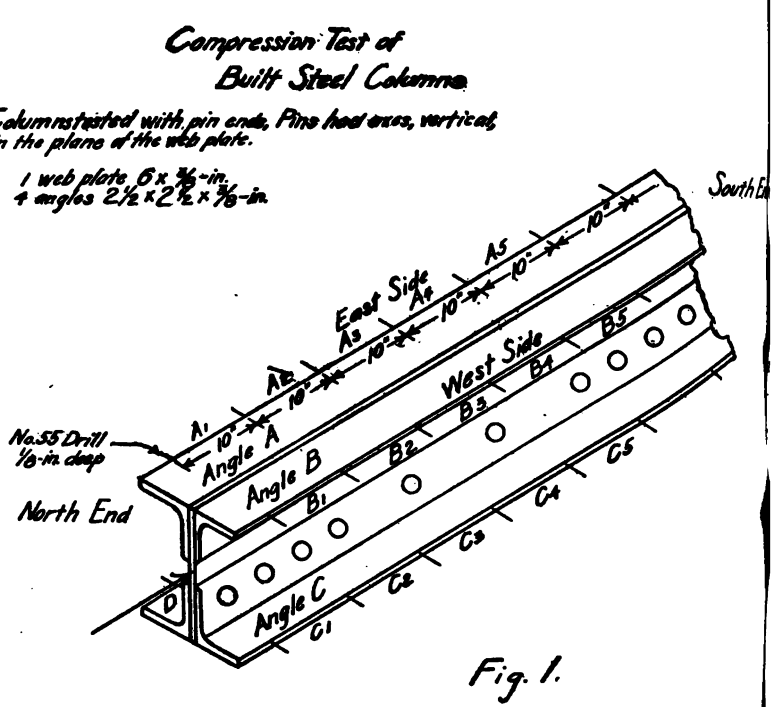

Fig. 1.

No. 418.

Built I column, 60,000 lb. carbon steel.
Pin ends.
Length of column = 216.32 in. = 18 ft. 0.32 in.
Length from center to center of pins = 225.02 in. = 18 ft. 9.02 in.
Weight = 579 lbs.
Sectional area = 9.066 sq. in.
Gauged lengths as per fig. 1.
Counterweighted at middle.

No. 419.

Built I column, 60,000 lbs. carbon steel.
Pin ends.
Length of column = 216.30 in. = 18 ft., 0.30 in.
Length from center to center of pins = 225 in. = 18 ft., 9 in.
Weight = 574 lbs.
Sectional area = 8.985 sq. in.
Gauged lengths as per Fig. 1.
Counterweighted at middle.

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MODEL BREECH BUSHINGS.

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TESTS OF MODEL BREECH BUSHINGS TO DETERMINE THE RELATIVE EFFICIENCY OF CYLINDRICAL AND CONICAL BUSHINGS.

The tests were made on four models, "A" and "C" having cylindrical jackets and plugs and "B" and "D" having conical jackets and plugs, and on two additional models, 7T3 having a conical jacket and plug and 7T4 having a cylindrical jacket and plug. Model 7T3 with the conical jacket and plug also has a reinforcing steel band flush with the end of the jacket and face of the plug. The method of applying the load is shown in fig. 1.

"A" and "B" were first tested by successive applications of loads, increasing the load each time by 25,000 pounds. The column X refers to the depth marked X in fig. 1. This measurement was made after each load.

Model "A."

Load.	X.	
Lbs.		
25,000	4.00	
50,000	4.00	
75,000	4.00	
100,000	4.00	
125,000	4.00	
150,000	4.00	
175,000	4.00	
200.000	4.00	
225,000	4.00	
250,000	4.01	Plug started.
275.000	4.015	Plug slightly crowned.
300,000	4.03	Plug crowned more.
325,000	4.03	Plug crowned still more. Plunger upset and a tight fit. Turned to a smaller diameter.
350,000	4.05	
375,000	4.08	
400,000	4.09	
425,000	4.11	Plunger tight, also bushing tight on jacket. Both plunger and bushing machined to give clearance. On reapplying the load the jacket burst, as shown on photograph "1," at a load of 383,000 pounds.

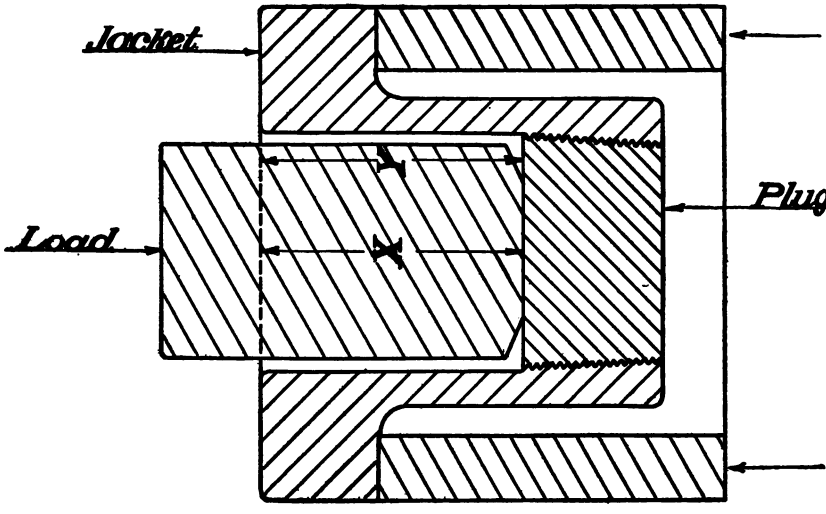

Fig. 1.

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Model "B."

Load.	X.	
Lbs.		
0	4.03	
25,000	4.03	
50,000	4.03	
75,000	4.03	
100,000	4.03	
125,000	4.03	
150,000	4.03	
175,000	4.03	
200,000	4.03	Plug began to crown.
225,000	4.03	
250,000	4.04	
275,000	4.04	
300,000	4.05	
319,200	.....	Jacket burst, as shown in photograph "2."

Models "C" (cylindrical) and "D" (conical) were tested under a repeated load.

Load, 250,000 lbs.

Number of applications of load.	Measurement "X."	
	Model "C."	Model "D."
0	4.00	4.00
25	4.01	4.01
50	4.01	4.01
150	4.01	4.02—
200	4.02	4.02—
300	4.02	4.02—
400	4.02	4.02—
425	4.02	4.02—
Load increased to 260,000 lbs.		
450	4.02	4.02
Load increased to 270,000 lbs.		
475	4.02	4.02+
Load increased to 280,000 lbs.		
500	4.02	4.02+
Load increased to 300,000 lbs.		
505	4.02	4.03
Load increased to 325,000 lbs.		
506	4.03	4.05
510	4.03	4.05
Load increased to 350,000 lbs.		
511	4.04	(1)
Load increased to 375,000 lbs.		
512	4.07	.....

[1] "D" broke at 333,600 lbs. See photograph "4."

Load increased until "C" broke at 380,100 lbs., as shown in photograph "3."

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7T3. Conical jacket and plug, plunger slightly crowned.

HARDNESS.

Plug.		Jacket.	
Shore.	Brinell's.	Shore.	Brinell's.
37.5	228	37	207

Load.	X.	Y.*	
Lbs.			
0	3.75	.....	
25,000	3.75	.....	
50,000	3.75	.....	
75,000	3.75	.....	
100,000	3.75	.....	
125,000	3.75	.....	
150,000	3.75	.....	
175,000	3.75	.....	
200,000	3.75	.....	
225,000	3.75+	.....	Plug slightly crowned.
250,000	3.75+	.....	
275,000	3.75+	.....	
300,000	3.75+	.....	Plug indented by plunger.
325,000	3.75+	.....	
350,000	3.75+	.....	Plug crowned more.
375,000	3.76—	.....	
400,000	3.76	.....	
425,000	3.76+	.....	
450,000	3.76+	.....	Plug crowned still more.
475,000	3.77	3.76	
500,000	3.78	3.77+	
525,000	3.80	3.78	Diameter over reinforcing ring, 5.25 in.
Jacket again placed in testing machine, at 524,300 lbs.			Sheared the thread in jacket and pushed the plug out of jacket, as shown in photograph "7."

Maximum diameter over reinforcing ring, 5.26 inches.
Minimum diameter over reinforcing ring, 5.25 inches.
* The column "Y" refers to the depth marked "Y" in fig. 1.

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7T4. Cylindrical jacket and plug, plunger slightly crowned.

Plug.		Jacket.	
Shore.	Brinell's.	Shore.	Brinell's.
37	228	37.5	212

Load.	X.	Y.	
Lb.			
0	3.75	.....	Diameter of jacket and plug end, 4.24 in.
25,000	3.75	.....	
50,000	3.75	.....	
75,000	3.75	.....	
100,000	3.75	.....	
125,000	3.75	.....	
150,000	3.75	.....	
175,000	3.75	.....	
200,000	3.75	.....	Plug slightly crowned.
225,000	3.75	.....	
250,000	3.75	.....	
275,000	3.75	.....	Plug indented slightly by plunger.
300,000	3.75+	.....	
325,000	3.75+	.....	
350,000	3.75+	.....	Plug crowned more.
375,000	3.75+	.....	
400,000	3.76—	.....	
425,000	3.76—	.....	
450,000	3.76+	3.76	Joint between jacket and plug opening.
467,700	.....	.....	Ultimate strength.

Sheared the thread in jacket and pushed plug out a little, as shown in photograph 8.

Maximum diameter of jacket at the plug end, 4.37 inches.

Minimum diameter of jacket at the plug end, 4.30 inches.

At 176,200 lbs. the plug started and was pushed out about 0.45 inch, as shown in photograph 9.

At 2,500 lbs. plug started and was pushed out of jacket, as shown in photograph 10.

In all cases, except that of C, the tendency of shearing the threads was apparent, and in the cases of 7T3 and 7T4 this was the method of failure. Failure occurred in A, B, C, and D by the fracture of the jackets, due, undoubtedly, to the condition of the metal. Photograph 5 shows the shearing of the threads in model "B." The photographs of 7T3 and 7T4 in which the stripped threads appear show that the thread from the conical jacket was sheared much nearer the base of the thread than was true in the case of the thread of the cylindrical jacket, indicating that these threads were more firmly in mesh at the time of the stripping. This is also confirmed by the fact that, in the case of the cylindrical jacket, which had no reinforcement, the diameter was increased about 0.1 inch, while the reenforced conical jacket showed an increase of diameter of only 0.01 inch.

All the fractures of jackets A, B, C, and D were coarse and crystalline. Microphotographs taken from the fragments broken from the jackets of A and B indicate that the metal has been heated too far above the critical point, held at this temperature too long, and then cooled too slowly. This is shown by the inclosed microphotographs, 11 and 12, which show clear-cut veins of ferrite, and well-developed lamellar structure in the pearlite. Pieces of these two

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jackets were heated to 750° C. for two hours and cooled in air. Micro photographs 13 and 14 show the resulting structures.

The results of all physical tests made on any of the material used i these models are here given. From each of the models "C" and "D two longitudinal and two tangential specimens were taken. Th longitudinal specimens were marked C2, C3, D2, and D3; the tan gential specimens were marked C1, C4, D1, and D4. C1, C2, D1 and D2 were tested in the condition in which they were taken fro the models. C3, C4, D3, and D4 were heated to 750° C., held fo two hours, and cooled in air. Two specimens, marked 7T1 and 7T were received from Watervliet Arsenal, and represent the materi used in models 7T3 and 7T4.

Chemical analysis showed the following composition:

Mark.	C.	Mn.	Si.	S.	P.	Ni.
7T1....	0.33	0.60	0.214	0.026	0.037	3.10
7T2....	.34	.62	.203	.025	.037	3.15

The physical test gave the following physical properties:

Marks.	Elastic limit.	Tensile strength.	Elongation.	Contraction.	Hardness.	
					Shore.	Brinell.
C1.....	43,500	95,000	13.0	16.9	26.5	179
D1.....	43,000	96,000	17.5	27.4	25.0	183
C2.....	53,000	95,000	11.0	20.0	24.0	179
D2.....	55,000	96,000	16.5	30.0	23.0	179
C3.....	47,000	94,000	22.5	47.0	21.0	179
D3.....	52,000	98,000	18.5	43.0	22.0	179
C4.....	50,000	96,500	16.0	24.0	29.0	179
D4.....	47,500	96,000	18.0	20.5	28.0	183
7T1....	77,000	101,000	25.5	67.0	32.0	207
7T2....	77,000	101,000	24.5	64.7	32.0	207

C1, D1, C2, and D2, as taken from the model.

C3, D3, C4, and D4, heated to 750° C. and held two hours. Cooled in air.

List of photographs.

1. Breech bushing "A" after failure.
2. Breech bushing "B" after failure.
3. Breech bushing "C" after failure.
4. Breech bushing "D" after failure.
5. Breech bushing "B" after failure, showing shearing of thread
6. Breech bushing 7T3 after failure.
7. Plug from breech bushing 7T3 after failure.
8. Breech bushing 7T4 after plug had started.
9. Breech bushing 7T4 after plug was nearly out.
10. Breech bushing 7T4 after failure.
11. Microphotograph of breech bushing "A" as received.
12. Microphotograph of breech bushing "B" as received.
13. Microphotograph of breech bushing "A" after treatment.
14. Microphotograph of breech bushing "B" after treatment.

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PHOTOGRAPH 1.

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PHOTOGRAPH 2.

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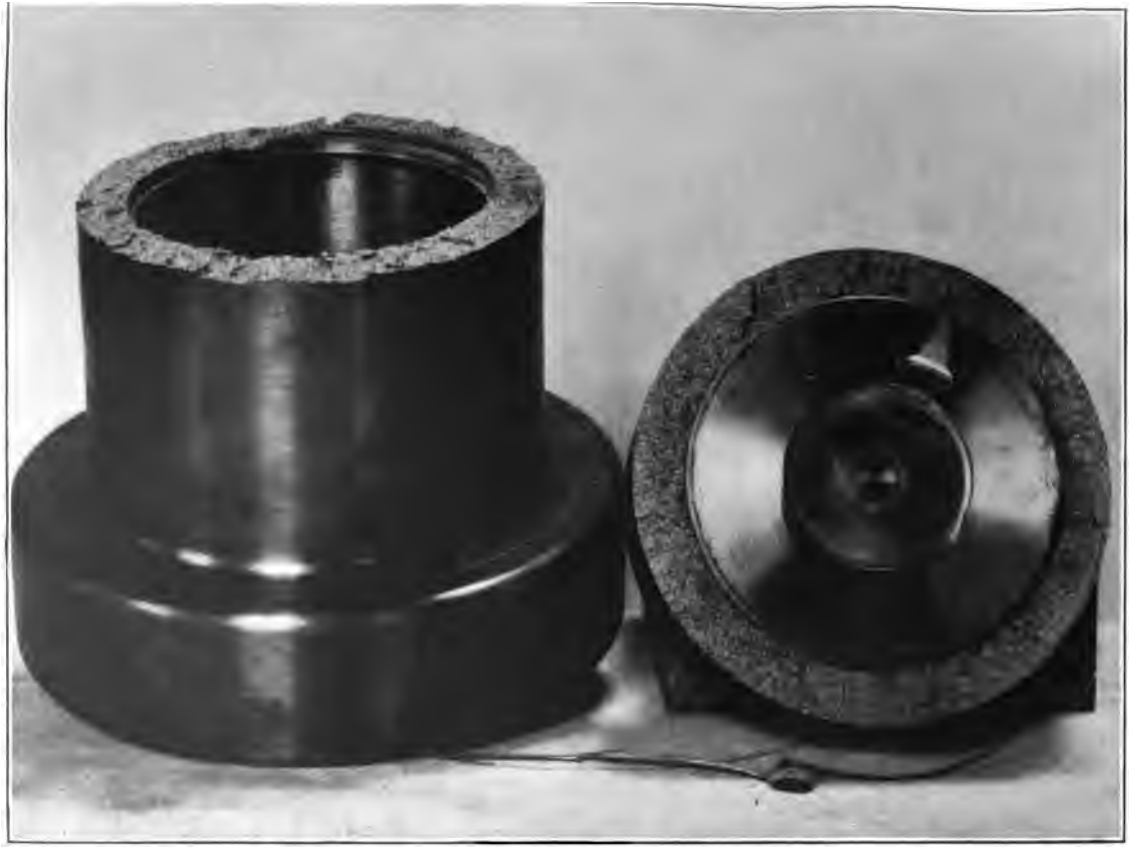

PHOTOGRAPH 3.

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PHOTOGRAPH 4.

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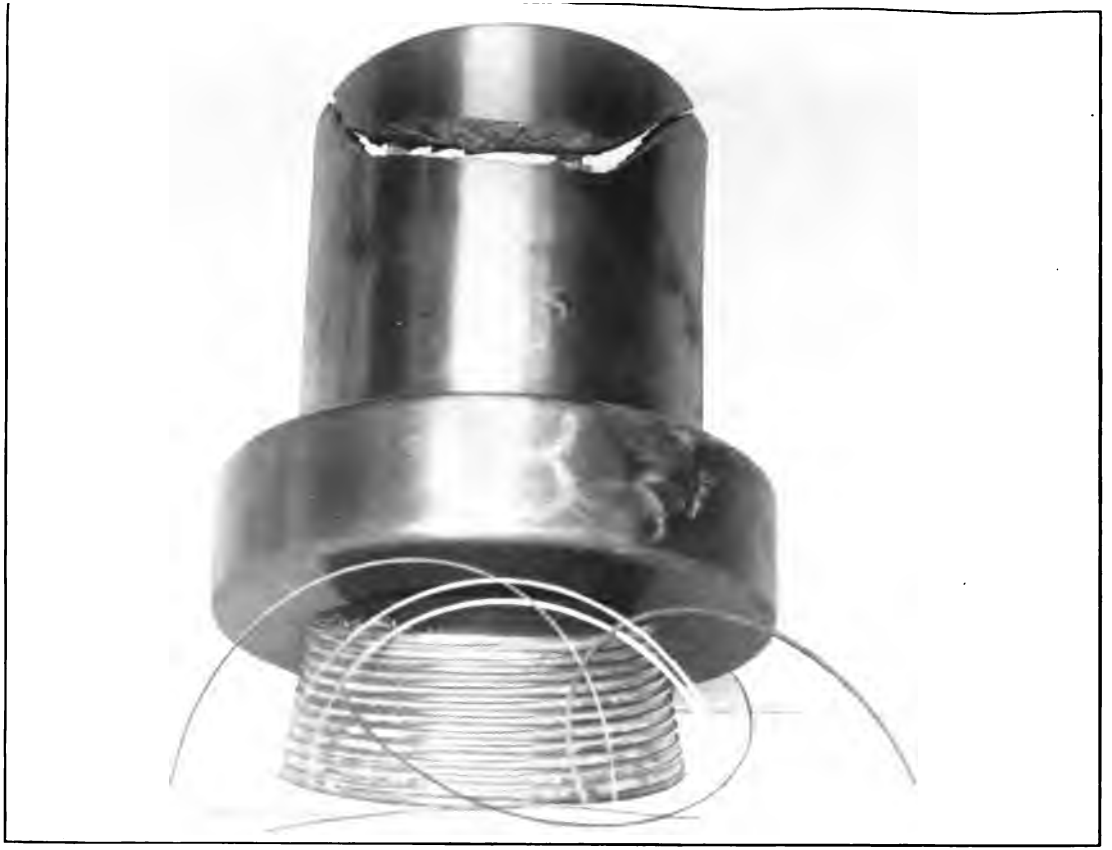

PHOTOGRAPH 5.

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PHOTOGRAPH 6.

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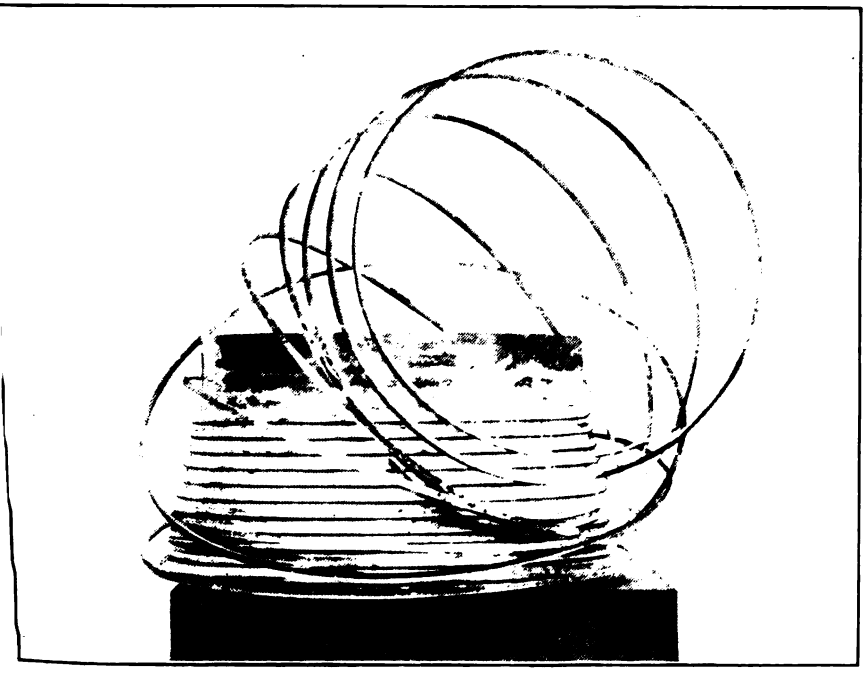

PHOTOGRAPH 7.

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PHOTOGRAPH 8.

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PHOTOGRAPH 9.

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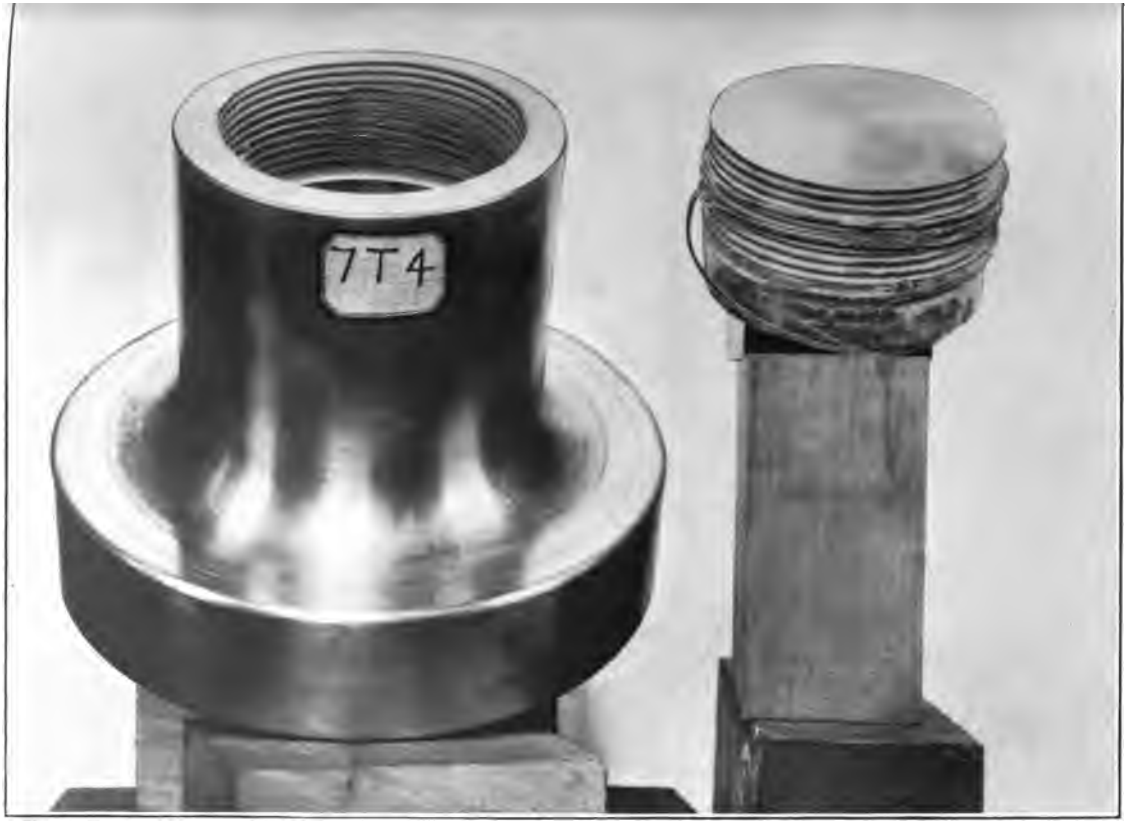

PHOTOGRAPH 10.

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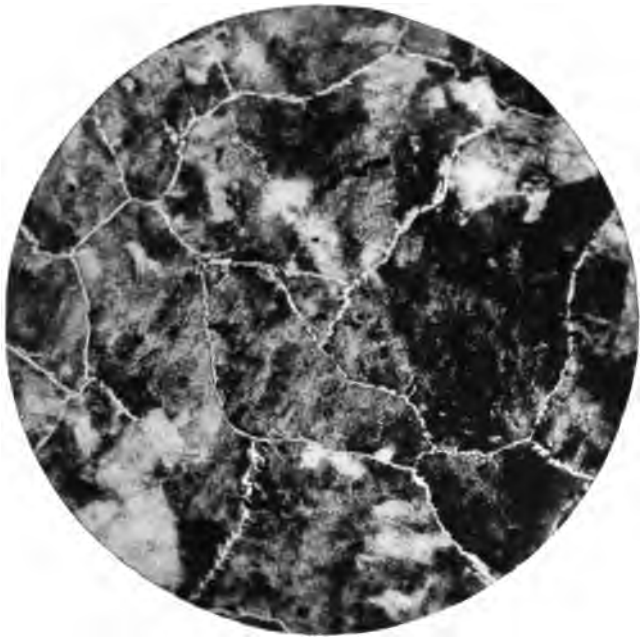
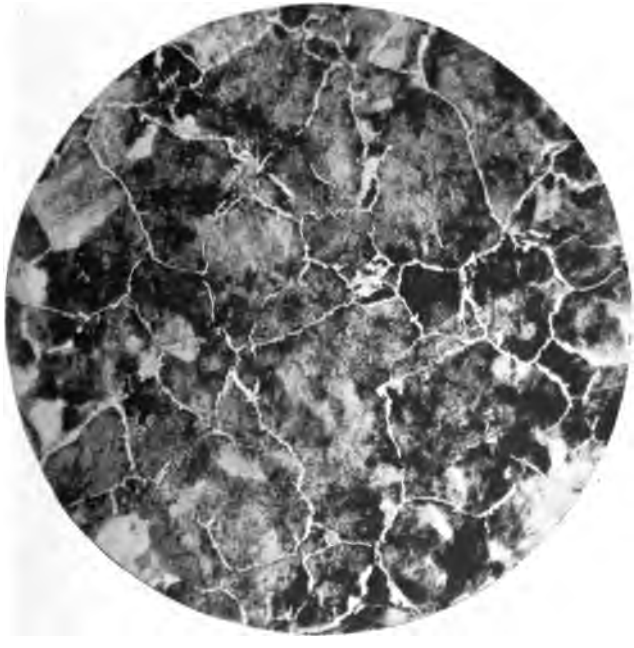


MICROPHOTOGRAPH FROM B.



MICROPHOTOGRAPH FROM A.

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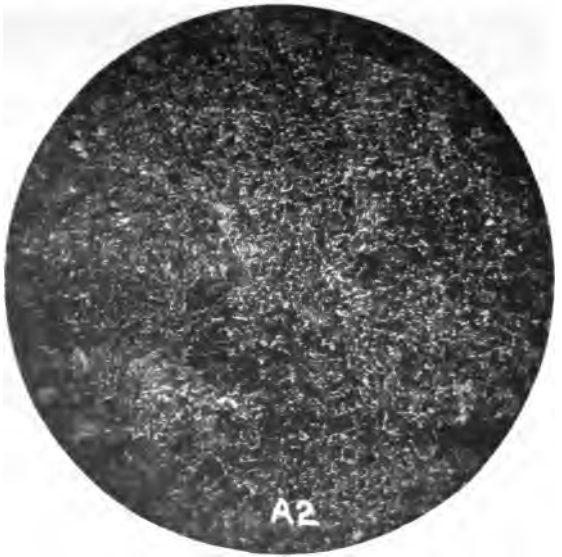
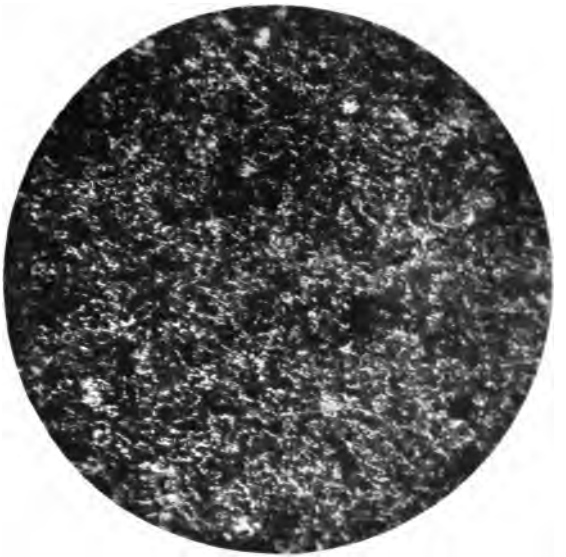


BREECH BUSHING, A2. X50.



BREECH BUSHING, B2. X50.

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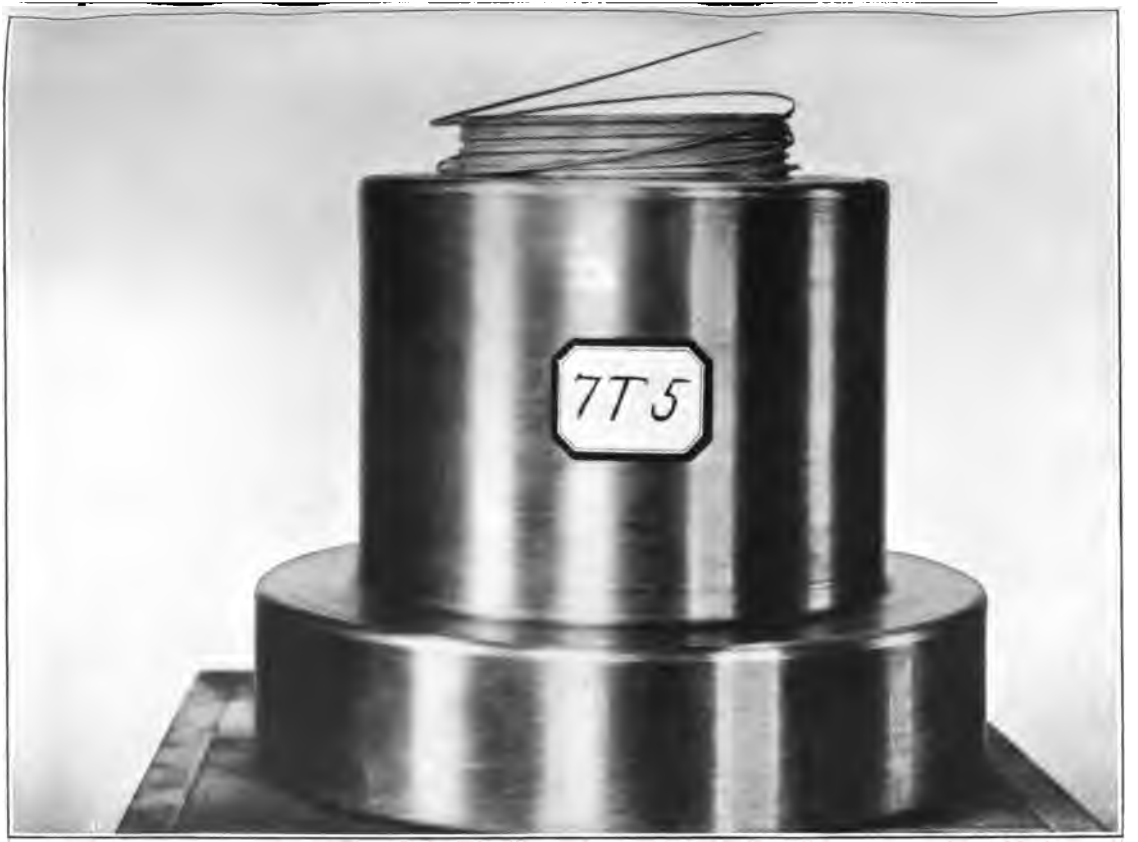

PHOTOGRAPH 15.

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PHOTOGRAPH 16.

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No. 482.

TESTS OF MODEL BREECH BUSHINGS TO DETERMINE THE RELATIVE EFFICIENCY OF SQUARE AND V THREADS.

7T5 had a square thread and 7T6 had a V thread. Depths were measured (see Fig. 1 in previous test) after increased loads of 25,000 lbs.

7T5.

Applied loads.	Depth X.	Remarks.
Total lbs.	*Inches.*	
0	3.76	
25,000	3.76	
50,000	3.76	
75,000	3.76	
100,000	3.76	
125,000	3.76	
150,000	3.76	Plug slightly crowning.
175,000	3.76	
200,000	3.76	
225,000	3.76	
250,000	3.76+	
275,000	3.76+	Plug little more crowning.
300,000	3.76+	
325,000	3.77−	Do.
350,000	3.77−	Joint between plug and jacket slightly open.
375,000	3.77	
400,000	3.77	
425,000	3.77+	Diameter across jacket and plug, 5.26 ins.
450,000	3.79	Plug pushed out of jacket about 0.02 in.
460,700	.....	Ultimate strength.
.....	.....	Sheared the threads in jacket. Pushed plug out of jacket 0.57 in.

7T6.

Applied loads.	Depth X.	Remarks.
Total lbs.	*Inches.*	
0	3.78	
25,000	3.78	
50,000	3.78	
75,000	3.78	
100,000	3.78	
125,000	3.78	
150,000	3.78	
175,000	3.78	
200,000	3.78	
225,000	3.78	
250,000	3.78	
275,000	3.78+	
300,000	3.78+	Plug slightly crowning.
325,000	3.78+	
350,000	3.78+	Plug little more crowning.
375,000	3.78+	
400,000	3.79−	Joint between plug and jacket slightly open.
425,000	3.79	Plug little more crowning.
450,000	3.79+	Joint between plug and jacket little more open.
475,000	3.80+	Diameter across jacket and plug, 5.26− in.
500,000	3.81	Diameter across jacket and plug, 5.26+ in.
518,200	.....	Ultimate strength.
.....	.....	Sheared the threads in jacket. Pushed plug out of jacket 0.16 in. on one side, 0.02 in. on the other.

Photographs 15 and 16 show each model after failure.

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RACK AND PAWL.

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The object of this test was to determine the load at which the pawl teeth shown in figure 1 would fail.

The apparatus used and the points of taking measurements are also shown in figure 1.

Measurements were taken after each load between the points indicated on the drawing as follows: Measurements E, F, and G were taken with inside micrometers, measurements AK, BK, CH, DH, and LM were made with a vernier scale reading to 0.01 in., these five readings being taken on both the east and west sides of the teeth. Before and after the test the following measurements were also taken on both sides of the teeth: AN, BN, CO, and DO. As the test progressed measurements were also taken with a thickness gauge between teeth A and D, and also at points P and R.

A load of 5,000 pounds was first applied and measurements taken. Then beginning with a load of 10,000 pounds, the load was increased by increments of 10,000 pounds up to 120,000 lbs., when the load increments became 5,000 pounds. After each increase of load, measurements and impressions were taken and the load was again reduced to 5,000 pounds and remeasured.

The results are as follows:

The differences between the micrometer reading and the original reading are here tabulated.

Load.	E.	F.	G.	Load.	E.	F.	G.
Lb.	*In.*	*In.*	*In.*	*Lb.*	*In.*	*In.*	*In.*
5,000	0.	0.	0.	5,000	.0184	.0188	.0065
10,000	.0032	.0023	.0017	175,000	.0707	.0569	.0366
5,000	.0022	.0011	.0001	5,000	.0196	.0198	.0073
20,000	.0064	.0055	.0035	180,000	.0735	.0594	.0370
5,000	.0027	.0012	.0007	5,000	.0217	.0220	.0080
30,000	.0119	.0084	.0058	185,000	.0764	.0616	.0392
5,000	.0045	.0022	.0007	5,000	.0221	.0230	.0087
40,000	.0167	.0117	.0077	190,000	.0800	.0641	.0413
5,000	.0043	.0019	.0008	5,000	.0230	.0239	.0098
50,000	.0201	.0144	.0102	195,000	.0827	.0666	.0425
5,000	.0051	.0019	.0011	5,000	.0250	.0256	.0107
60,000	.0251	.0176	.0114	200,000	.0867	.0695	.0447
5,000	.0064	.0034	.0008	5,000	.0275	.0275	.0117
70,000	.0295	.0199	.0133	205,000	.0901	.0732	.0473
5,000	.0068	.0042	.0008	5,000	.0289	.0297	.0132
80,000	.0312	.0227	.0150	210,000	.0937	.0761	.0492
5,000	.0072	.0040	.0011	5,000	.0309	.0314	.0143
90,000	.0355	.0249	.0166	215,000	.0973	.0800	.0512
5,000	.0082	.0049	.0013	5,000	.0329	.0330	.0163
100,000	.0402	.0278	.0187	220,000	.1009	.0840	.0545
5,000	.0093	.0061	.0019	5,000	.0347	.0352	.0174
110,000	.0427	.0311	.0205	225,000	.1051	.0869	.0562
5,000	.0098	.0066	.0020	5,000	.0386	.0382	.0190
120,000	.0477	.0340	.0227	230,000	.1106	.0906	.0587
5,000	.0101	.0081	.0023	5,000	.0405	.0415	.0218
125,000	.0480	.0356	.0235	235,000	.1137	.0937	.0623
5,000	.0108	.0084	.0024	5,000	.0435	.0440	.0218
130,000	.0499	.0361	.0248	240,000	.1191	.0991	.0684
5,000	.0121	.0091	.0030	5,000	.0477	.0492	.0298
135,000	.0516	.0383	.0253	245,000	.1261	.1066	.0746
5,000	.0123	.0101	.0035	5,000	.0516	.0534	.0332
140,000	.0542	.0404	.0269	250,000	.1323	.1125	.0780
5,000	.0128	.0104	.0043	5,000	.0551	.0577	.0378
145,000	.0563	.0415	.0285	255,000	.1372	.1174	.0839
5,000	.0140	.0111	.0043	5,000	.0601	.0627	.0420
150,000	.0576	.0433	.0302	260,000	.1476	.1267	.0901
5,000	.0141	.0122	.0045	5,000	.0673	.0692	.0478
155,000	.0611	.0456	.0311	265,000	.1550	.1337	.0955
5,000	.0156	.0127	.0055	5,000	.0752	.0753	.0539
160,000	.0634	.0478	.0319	270,000	.1568	.1415	.1025
5,000	.0164	.0138	.0057	5,000	.0775	.0817	.0580
165,000	.0653	.0501	.0332	275,000	.1708	.1492	.1099
5,000	.0176	.0156	.0063	5,000	.0855	.0888	.....
170,000	.0682	.0546	.0351				

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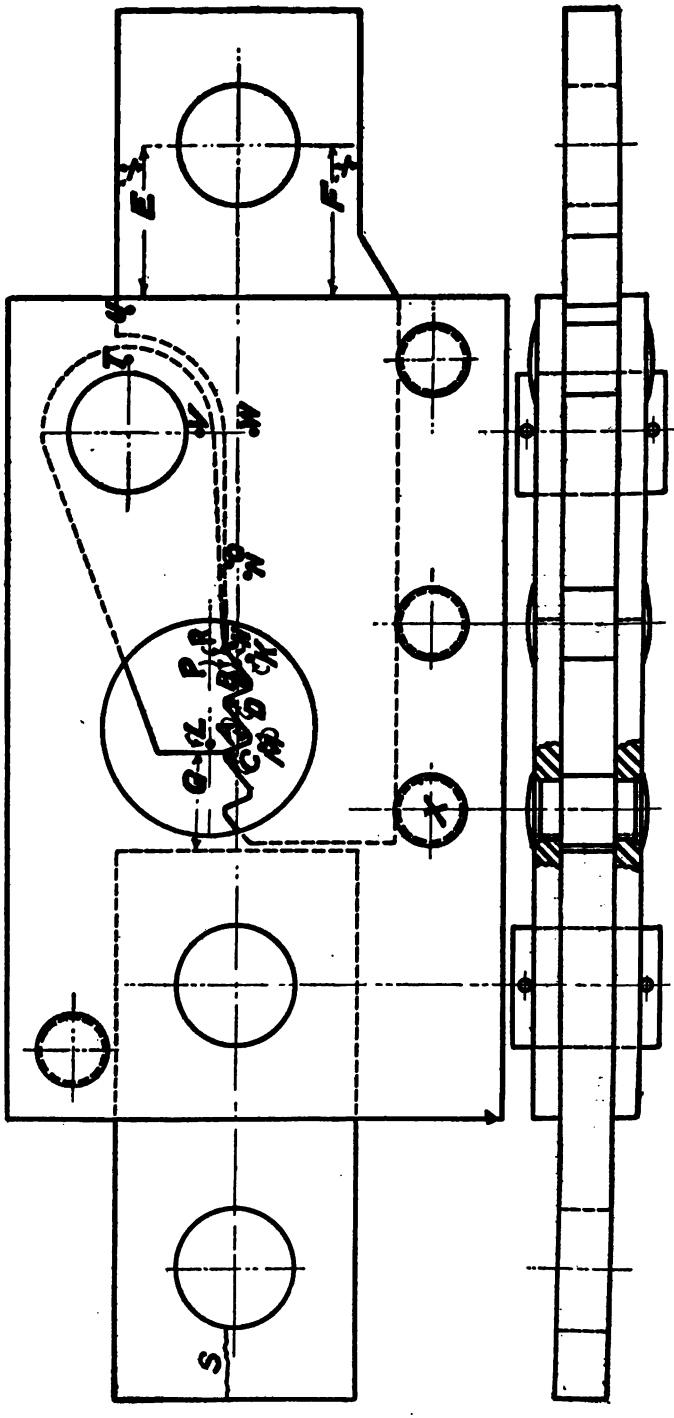

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Thickness gauge readings.

Load.	AB.	P.	R.	Load.	AB.	P.	R.
Lb.	*In.*	*In.*	*In.*	*Lb.*	*In.*	*In.*	*In.*
5,000	0.004	0.008	.....	5,000	.....	.....	.....
135,000	.008	.014	.....	210,000	.014	.027	.....
5,000	.004	.008	.....	5,000	.012	.016	.....
140,000	.008	.014	.....	215,000	.014	.031	.....
5,000	.006	.008	.....	5,000	.012	.018	.....
145,000	.008	.015	.....	220,000	.015	.033	.....
5,000	.006	.008	.....	5,000	.012	.020	.....
150,000	.008	.015	.....	225,000	.015	.037	.....
5,000	.006	.008	.....	5,000	.012	.020	.....
155,000	.008	.015	.....	230,000	.016	.033	.....
5,000	.006	.008	.....	5,000	.012	.022	.....
160,000	.008	.018	.....	235,000	.016	.037	.....
5,000	.006	.010	.....	5,000	.012	.022	.....
165,000	.010	.018	.....	240,000	.016	.043	.....
5,000	.008	.010	.....	5,000	.014	.026	.....
170,000	.010	.020	.....	245,000	.018	.049	.....
5,000	.008	.012	.....	5,000	.015	.025	.....
175,000	.010	.021	.....	250,000	.020	.041	.....
5,000	.008	.012	.....	5,000	.015	.027	.012
180,000	.010	.022	.....	255,000	.020	.043	.021
5,000	.008	.012	.....	5,000	.015	.028	.012
185,000	.012	.023	.....	260,000	.021	.047	.022
5,000	.010	.014	.....	5,000	.018	.032	.012
190,000	.012	.024	.....	265,000	.023	.049	.023
5,000	.010	.014	.....	5,000	.018	.033	.012
195,000	.012	.024	.....	270,000	.024	.053	.023
5,000	.010	.015	.....	5,000	.018	.035	.012
200,000	.012	.027	.....	275,000	.024	.053	.023
5,000	.010	.016	.....	5,000	.017	.037	.014
205,000	.....	.....	.....				

Measurements of pawl.

Load.	AK	BK	CH	DH	LM
Lb.	*In.*	*In.*	*In.*	*In.*	*In.*
5,000	2.00	1.00	4.00	2.00	2.00
10,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
20,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
30,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
40,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
50,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
60,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
70,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
80,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
90,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
100,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
110,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
120,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
125,000	2.00	1.00	4.00	2.00	2.00
5,000	2.00	1.00	4.00	2.00	2.00
130,000	2.01	1.00	4.00	2.00	1.99
5,000	2.00	1.00	4.00	2.00	2.00
135,000	2.01	1.01	4.00	2.00	1.99
5,000	2.00	1.00	4.00	2.00	2.00
140,000	2.01	1.01	4.00	2.00	1.99
5,000	2.00	1.00	4.00	2.00	2.00
145,000	3.01	1.01	4.00	2.00	2.00
5,000	3.00	1.00	4.00	2.00	2.00
150,000	3.01	1.01	4.00	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
155,000	3.01	1.01	4.00	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00

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Measurements of pawl—Continued.

Load.	AK	BK	CH	DH	LM
Lb.	*In.*	*In.*	*In.*	*In.*	*In.*
160,000	3.01	1.01	4.01	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
165,000	3.01	1.01	4.01	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
170,000	3.01	1.01	4.01	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
175,000	3.01	1.01	4.01	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
180,000	3.01	1.01	4.01	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
185,000	3.01	1.01	4.01	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
190,000	3.01	1.01	4.01	2.01	2.00
5,000	3.00	1.00	4.00	2.00	2.00
195,000	3.02	1.01	4.02	2.01	2.00
5,000	3.01	1.01	4.01	2.01	2.00
200,000	3.02	1.02	4.02	2.02	2.00
5,000	3.01	1.01	4.01	2.01	2.00
205,000	3.02	1.02	4.02	2.02	2.00
5,000	3.01	1.01	4.01	2.01	2.00
210,000	3.02	1.02	4.02	2.02	2.00
5,000	3.01	1.01	4.01	2.01	2.00
215,000	3.02	1.02	4.02	2.02	2.00
5,000	3.01	1.01	4.01	2.01	2.00
220,000	3.02	1.02	4.02	2.03	2.00
5,000	3.01	1.01	4.01	2.01	2.00
225,000	3.02	1.02	4.02	2.03	2.00
5,000	3.01	1.01	4.01	2.01	2.00
230,000	3.03	1.03	4.03	2.03	2.00
5,000	3.02	1.02	4.02	2.02	2.00
235,000	3.03	1.03	4.03	2.03	2.00
5,000	3.02	1.02	4.02	2.02	2.00
240,000	3.03	1.03	4.03	2.02	2.00
5,000	3.02	1.02	4.02	2.02	2.00
245,000	3.03	1.04	4.03	2.04	2.00
5,000	3.02	1.02	4.02	2.03	2.00
250,000	3.04	1.04	4.04	2.04	2.00
5,000	3.03	1.02	4.02	2.02	2.00
255,000	3.04	1.04	4.04	2.04	2.00
5,000	3.03	1.03	4.03	2.03	2.00
260,000	3.04	1.04	4.05	2.05	2.00
5,000	3.03	1.03	4.03	2.03	2.00
265,000	3.04	1.05	4.05	2.05	2.00
5,000	3.03	1.03	4.03	2.03	2.00
270,000	3.05	1.05	4.05	2.05	2.00
5,000	3.04	1.04	4.04	2.04	2.00
275,000	3.05	1.05	4.05	2.06	2.00
5,000	3.04	1.04	4.04	2.04	2.00

EAST SIDE.

Measurements on pawl.

Load.	AK	BK	CH	DH	LM
Lb.	*In.*	*In.*	*In.*	*In.*	*In.*
5,000	3.02	1.02	4.00	2.00	2.00
10,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.02	4.00	2.00	2.00
20,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
30,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
40,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
50,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
60,000	3.02	1.01	4.00	1.99	2.00
5,000	3.02	1.01	4.00	2.00	2.00
60,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
70,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
80,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
90,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00

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FIG. 2.

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EAST SIDE—Continued.

Measurements on pawl—Continued.

Load.	AK	BK	CH	DH	LM
Lb.	*In.*	*In.*	*In.*	*In.*	*In.*
100,000	3.02	1.01	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
110,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.02	4.00	2.00	2.00
120,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
125,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
130,000	3.02	1.015	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
135,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
140,000	3.02	1.015	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
145,000	3.02	1.015	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
150,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
155,000	3.02	1.02	4.00	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
160,000	3.02	1.02	4.01	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
165,000	3.025	1.025	4.01	2.01	2.00
5,000	3.02	1.01	4.00	2.00	2.00
170,000	3.025	1.02	4.005	2.00	2.00
5,000	3.02	1.01	4.00	2.00	2.00
175,000	3.025	1.02	4.01	2.01	2.00
5,000	3.02	1.015	4.00	2.00	2.00
180,000	3.03	1.02	4.01	2.01	2.00
5,000	3.02	1.015	4.00	2.00	2.00
185,000	3.03	1.02	4.01	2.01	2.00
5,000	3.02	1.015	4.00	2.00	2.00
190,000	3.03	1.025	4.01	2.01	2.00
5,000	3.02	1.02	4.00	2.00	2.00
195,000	3.03	1.025	4.01	2.01	2.00
5,000	3.03	1.02	4.00	2.00	2.00
200,000	3.035	1.03	4.02	2.01	2.00
5,000	3.025	1.02	4.005	2.00	2.00
205,000	3.035	1.03	4.02	2.02	2.00
5,000	3.025	1.02	4.005	2.00	2.00
210,000	3.035	1.03	4.02	2.02	2.00
5,000	3.03	1.02	4.00	2.00	2.00
215,000	3.035	1.03	4.02	2.02	2.00
5,000	3.03	1.02	4.01	2.01	2.00
220,000	3.04	1.035	4.02	2.02	2.00
5,000	3.03	1.025	4.01	2.01	2.00
225,000	3.04	1.04	4.02	2.03	2.00
5,000	3.03	1.03	4.01	2.01	2.00
230,000	3.04	1.04	4.03	2.03	2.00
5,000	3.03	1.03	4.01	2.01	2.00
235,000	3.045	1.04	4.03	2.03	2.00
5,000	3.03	1.03	4.01	2.01	2.00
240,000	3.045	1.04	4.03	2.03	2.00
5,000	3.03	1.03	4.01	2.02	2.00
245,000	3.05	1.05	4.03	2.04	2.01
5,000	3.04	1.03	4.02	2.02	2.00
250,000	3.05	1.05	4.04	2.04	2.005
5,000	3.04	1.04	4.02	2.02	2.00
255,000	3.05	1.05	4.04	2.04	2.01
5,000	3.04	1.04	4.02	2.02	2.00
260,000	3.06	1.05	4.05	2.04	2.01
5,000	3.05	1.04	4.03	2.03	2.00
265,000	3.06	1.06	4.05	2.05	2.01
5,000	3.05	1.04	4.035	2.03	2.00
270,000	3.06	1.06	4.05	2.05	2.01
5,000	3.05	1.05	4.03	2.03	2.00
275,000	3.065	1.065	4.055	2.055	2.01
5,000	3.05	1.05	4.04	2.04	2.00

306,100 was the breaking load, failure occurring by the rupture of the link as shown on figure 1, by line S.

Figure 2 is a photograph of the apparatus after failure. At this load no tendency for the tooth and rack to separate in such a way as to get out of engagement was apparent, as shown by the lack of change in the measurement LM while the apparatus was under load.

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The following measurements were taken on both sides of the teeth before and after the test:

BEFORE THE TEST.

	CO.	DO.	AN.	BN.	LM.
West	7.01	5.00	6.01	4.00	2.01
East	7.01	5.02	6.01	4.00	2.02

AFTER THE TEST.

West	7.07	5.07	6.01	4.00	2.06
East	7.07	5.08	6.00	4.00	2.08

After the apparatus had been removed from the machine the rack and pawl were both examined and no apparent deformation of the pawl was found. Evidently all the deformation that occurred had taken place in the teeth of the rack. This is also apparent in the measurements CO, DO, AN, BN, and LM, taken before and after the test. These measurements were taken with the pawl and rack lying on a flat surface with their relative positions determined by the distances ST and UV, the measurement LM, and also a straight line drawn across the body of the pawl and the rack. The difference in the measurement LM before and after the test is due to the fact that the tooth D of the rack was forced forward so far that when the two pieces were in the correct relative positions after the test this tooth came in contact with tooth A, thus preventing it from fitting down to its former position between C and D. Figure 3 shows the pawl and rack in this relative position after the completion of the test.

Figures 4 and 5 show the relationship of the load plotted against each of the three measurements E, F, and G, and also the set in each of these measurements. The offset between E and F is indicative of a bending in the rack showing a tendency for this piece to straighten out. This tendency was further emphasized by the pronounced mark made on the edge of the rack through the pressure against the pin X, while it is comparatively slight in the cases of the other two pins. When it is considered that E is always considerably larger than F this evidence is quite conclusive.

These curves also serve as a check on the first observation of deformation of the teeth. The elastic limit was evidently quite near 160,000 pounds when the first signs of upsetting the teeth were discovered. It is apparent, however, that these results apply to the teeth of the rack and not to the teeth of the pawl, which are apparently unchanged.

The physical test of pawl and rack gave the following results:

PHYSICAL TEST OF PAWL.

Elastic limit.	Tensile strength.	Elongation.	Contraction.
Pounds. 83,080	*Pounds.* 133,800	*Per cent.* 16.5	*Per cent.* 54.6

PHYSICAL TEST OF RACK.

Pounds. 46,300	*Pounds.* 92,600	*Per cent.* 27.0	*Per cent.* 46.2

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CAST-STEEL RINGS.

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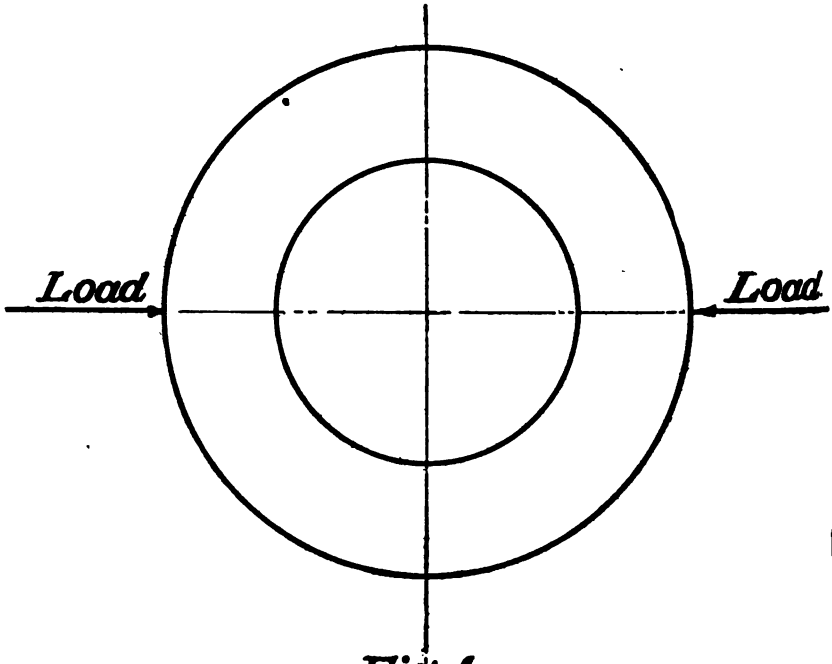

Fig. 1.

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TESTS OF TWO CAST-STEEL RINGS.

The rings were tested and the load applied as shown in fig. 1. Micrometer readings were taken on the two sides of the rings on the horizontal and vertical diameters, both internal and external, making eight readings under each load. The results are tabulated and also shown graphically in figs. 2 and 3.

Ring A.

[Inside dia.=6.748 in. Outside dia.=10.748 in. Length=3.998 in.]

Load.	Compression, inches, horizontal diameters.					
	Internal.			External.		
	West side.	East side.	Average.	West side.	East side.	Average.
Lb.						
1,000	0.	0.	0.	0.	0.	0.
10,000	.0021	.0018	.0020	.0018	.0022	.0020
20,000	.0040	.0037	.0039	.0043	.0044	.0043
30,000	.0064	.0060	.0062	.0083	.0081	.0082
40,000	.0084	.0078	.0081	.0101	.0101	.0101
Set 1,000	.0000	−.0001	.0000	−.0009	−.0009	−.0009
50,000	.0099	.0087	.0093	.0127	.0131	.0129
60,000	.0121	.0110	.0116	.0157	.0146	.0151
70,000	.0141	.0132	.0137	.0192	.0175	.0183
80,000	.0165	.0150	.0158	.0212	.0204	.0208
90,000	.0179	.0171	.0175	.0238	.0230	.0234
100,000	.0204	.0194	.0199	.0277	.0261	.0269
Set 1,000	.0007	.0007	.0007	.0013	.0008	.0010
110,000	.0225	.0216	.0221	.0306	.0290	.0298
Set 1,000	.0010	.0010	.0010	.0026	.0014	.0020
120,000	.0253	.0245	.0249	.0338	.0326	.0332
130,000	.0287	.0273	.0280	.0383	.0365	.0374
140,000	.0323	.0315	.0319	.0431	.0409	.0420
150,000	.0377	.0365	.0371	.0497	.0486	.0492
175,000	.0781	.0756	.0769	.0752	.0831	.0792

Load.	Extension, inches, vertical diameters.					
	Internal.			External.		
	West side.	East side.	Average.	West side.	East side.	Average.
Lb.						
1,000	0.	0.	0.	0.	0.	0.
10,000	.0013	.0015	.0014	.0040	.0010	.0025
20,000	.0031	.0032	.0031	.0050	.0010	.0030
30,000	.0051	.0050	.0050	.0060	.0020	.0040
40,000	.0067	.0064	.0065	.0070	.0050	.0060
Set 1,000	.0002	.0000	.0001	.0010	−.0010	.0000
50,000	.0080	.0074	.0077	.0080	.0060	.0070
60,000	.0096	.0087	.0091	.0090	.0070	.0080
70,000	.0111	.0107	.0109	.0100	.0090	.0095
80,000	.0127	.0128	.0127	.0120	.0110	.0115
90,000	.0142	.0142	.0142	.0140	.0120	.0130
100,000	.0160	.0161	.0160	.0160	.0130	.0145
Set 1,000	.0006	.0008	.0007	.0010	.0000	.0005
110,000	.0181	.0180	.0180	.0170	.0150	.0160
Set 1,000	.0009	.0009	.0009	.0010	.0000	.0005
120,000	.0202	.0199	.0200	.0200	.0180	.0190
130,000	.0217	.0225	.0221	.0220	.0180	.0200
140,000	.0263	.0257	.0260	.0250	.0240	.0245
150,000	.0307	.0300	.0303	.0270	.0300	.0285
175,000	.0625	.0616	.0621	.0620	.0630	.0625

Elastic limit = 90,000 lbs.
Ultimate strength = 295,200 lbs.
Ring failed on one side by cracking along horizontal diameter.
Hardness: Shore = 28; Brinell = 170.

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Ring B.

[Inside dia.=5.749 in. Outside dia.=10.748 in. Length=4.000 in.]

Load.	Compression, inches, horizontal diameters.					
	Internal.			External.		
	West side.	East side.	Average.	West side.	East side.	Average.
Lb.						
1,000	0.	0.	0.	0.	0.	0.
25,000	.0021	.0025	.0023	.0046	.0051	.0048
50,000	.0047	.0054	.0051	.0099	.0097	.0098
Set 1,000	.0000	−.0006	−.0003	.0004	.0001	.0002
75,000	.0075	.0079	.0077	.0143	.0138	.0140
90,000	.0091	.0096	.0094	.0162	.0171	.0167
100,000	.0101	.0105	.0103	.0182	.0193	.0188
110,000	.0114	.0119	.0117	.0201	.0212	.0206
120,000	.0123	.0129	.0126	.0222	.0237	.0230
130,000	.0136	.0141	.0139	.0241	.0257	.0249
140,000	.0148	.0154	.0151	.0261	.0279	.0270
Set 1,000	.0004	.0006	.0005	.0035	.0047	.0041
150,000	.0161	.0167	.0164	.0285	.0301	.0293
160,000	.0173	.0181	.0177	.0302	.0321	.0312
170,000	.0191	.0196	.0194	.0330	.0347	.0339
Set 1,000	.0021	.0020	.0020	.0053	.0067	.0060
180,000	.0208	.0211	.0210	.0352	.0372	.0362
190,000	.0225	.0232	.0229	.0381	.0403	.0392
200,000	.0251	.0259	.0255	.0413	.0447	.0430
220,000	.0321	.0310	.0316	.0506	.0534	.0521
240,000	.0442	.0450	.0446	.0645	.0687	.0661

Load.	Extension, inches, vertical diameters.					
	Internal.			Externe		
	West side.	East side.	Average.	West side.	East side.	Average.
Lb.						
1,000	0.	0.	0.	0.	0.	0.
25,000	.0018	.0019	.0018	.0020	.0030	.0025
50,000	.0038	.0039	.0038	.0040	.0050	.0045
Set 1,000	.0001	.0000	.0000	.0010	.0020	.0015
75,000	.0054	.0055	.0054	.0060	.0070	.0065
90,000	.0066	.0069	.0067	.0060	.0090	.0075
100,000	.0076	.0078	.0077	.0060	.0090	.0075
110,000	.0083	.0086	.0084	.0070	.0090	.0080
120,000	.0093	.0096	.0094	.0070	.0110	.0090
130,000	.0100	.0105	.0102	.0090	.0120	.0105
140,000	.0108	.0114	.0111	.0090	.0130	.0110
Set 1,000	.0004	.0004	.0004	.0000	.0030	.0015
150,000	.0121	.0126	.0123	.0100	.0150	.0125
160,000	.0129	.0139	.0134	.0110	.0160	.0135
170,000	.0011	.0150	.0145	.0120	.0170	.0145
Set 1,000	.0140	.0014	.0012	.0050	.0030	.0040
180,000	.0155	.0165	.0160	.0140	.0200	.0170
190,000	.0172	.0180	.0176	.0150	.0200	.0175
200,000	.0187	.0199	.0193	.0160	.0200	.0180
220,000	.0233	.0247	.0240	.0190	.0250	.0220
240,000	.0306	.0339	.0332	.0290	.0300	.0295

Elastic limit = 130,000 lbs.
Ultimate strength = 315,000 lbs.
Ring failed on one side by cracking along horizontal diameter.
Hardness: Shore = 27; Brinell = 163.

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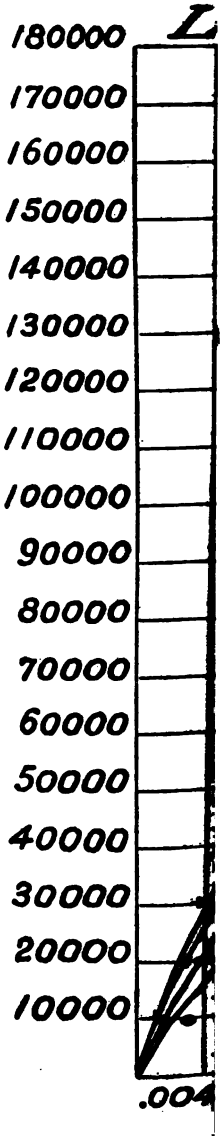

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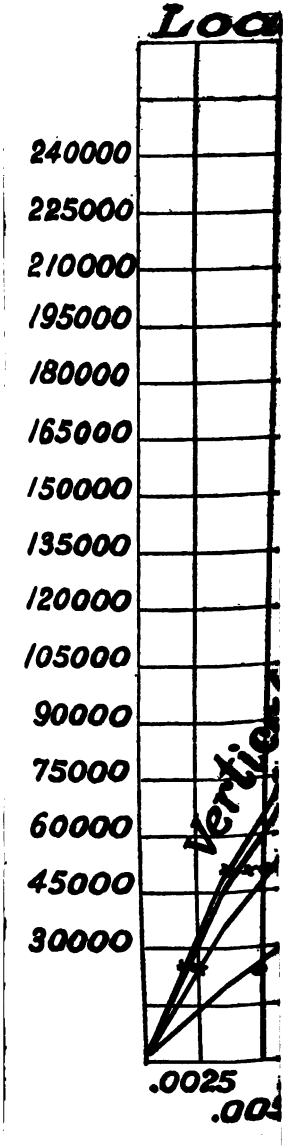

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Two test specimens were taken, one from the top end of the casting and the other from the bottom end, before the rings were cut off for machining. The specimens were marked 1 and 2, respectively.

Marks, 1.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Load (lb. per sq. in.).	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
	In.	*In.*	*In.*	*In.*	
1,000	0.	0	0.	0.	Initial load.
5,000	.0002	0	.00010	.00010	
10,000	.0005	.....	.00025	.00015	
20,000	.0014	.....	.00070	.00045	
30,000	.0022	.....	.00110	.00040	
35,000	.0026	0	.00130	.00020	
36,000	.0028	.....	.00140	.00010	
37,000	.0028	.....	.00140	.00000	
38,000	.0029	.....	.00145	.00010	
39,000	.0030	.....	.00150	.00005	
40,000	.0031	.....	.00155	.00005	
41,000	.0032	.....	.00160	.00005	Elastic limit.
42,000	.0034	.....	.00170	.00010	
43,000	.0036	.....	.00180	.00010	
44,000	.0174	.....	.00870	.00690	
45,000	.0186	.....	.00930	.00060	
46,000	.0202	.....	.01010	.00080	
47,000	.0223	.....	.01115	.00105	
48,000	.0238	.....	.01190	.00075	
83,500	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.43 in. in 2 in. = 21.5 per cent.
Elongation of inch sections, 0.26 in., 0.17 in.
Diameter at fracture, 0.43 in.
Sectional area, 0.145 sq. in.
Contraction of area, 27.4 per cent.
Position of fracture, 1.06 in. from the neck.
Appearance of fracture, fine granular, 70 per cent; silky, 30 per cent.

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Marks, 2.
Diameter, 0.505 in.
Sectional area, 0.20 sq. in.
Gauged length, 2 in.

Load (lb. per sq. in.).	In gauged length.		Per inch.		Remarks.
	Elongation.	Set.	Elongation.	Successive elongation.	
	In.	*In.*	*In.*	*In.*	
1,000	0.	0	0.	0.	Initial load.
5,000	.0002	0	.00010	.00010	
10,000	.0005	.....	.00025	.00015	
20,000	.0013	.....	.00065	.00040	
30,000	.0021	.....	.00105	.00040	
35,000	.0026	0	.00130	.00025	
36,000	.0026	.....	.00130	.00000	
37,000	.0027	.....	.00135	.00005	
38,000	.0028	.....	.00140	.00005	
39,000	.0029	.....	.00145	.00005	
40,000	.0030	.....	.00150	.00005	Elastic limit.
41,000	.0032	.....	.00160	.00010	
42,000	.0037	.....	.00185	.00025	
43,000	.0126	.....	.00630	.00445	
44,000	.0144	.....	.00720	.00090	
45,000	.0156	.....	.00780	.00060	
46,000	.0187	.....	.00935	.00155	
85,000	.....	.....	.....	.....	Tensile strength.

Elongation after fracture, 0.44 in. in 2 in. = 22 per cent.
Elongation of inch sections, 0.24 in., 0.20 in.
Diameter at fracture, 0.43 in.
Sectional area, 0.145 sq. in.
Contraction of area, 27.4 per cent.
Position of fracture, 1.20 in. from the neck.
Appearance of fracture, fine granular, 50 per cent; silky, 50 per cent.

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HEATING AND COOLING CURVES.

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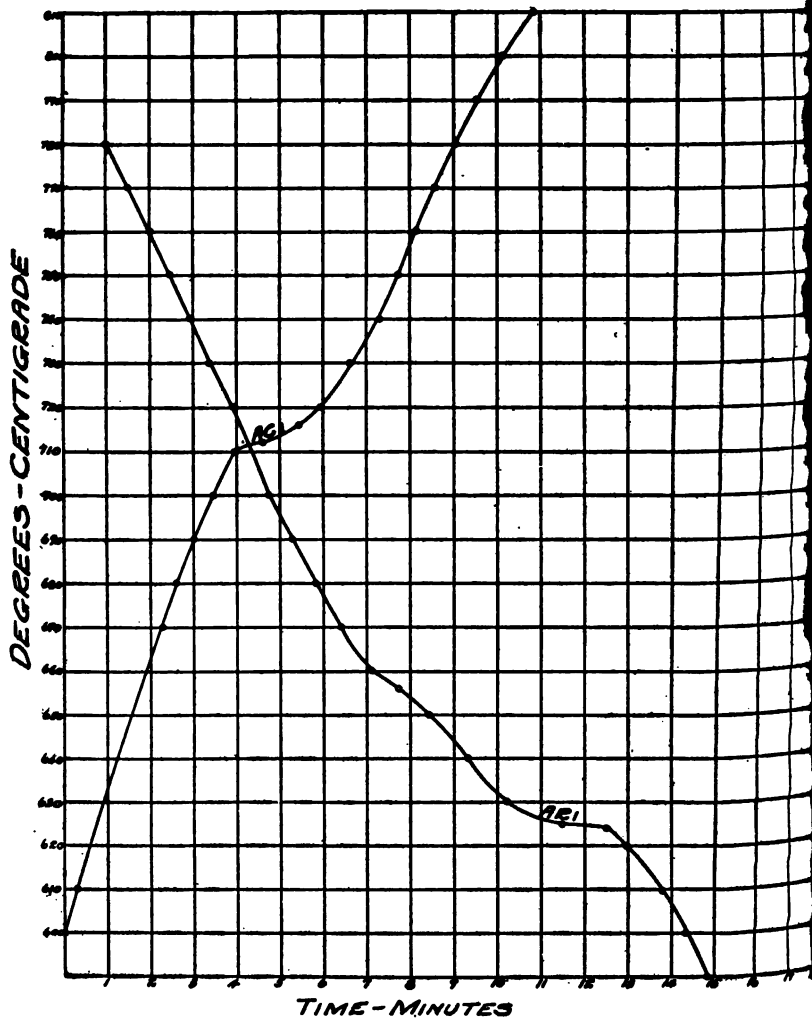
Heating and cooling curves taken on various grades of Arsen steels are shown on the following pages. The steels were heated i an electric muffle furnace and the temperatures measured with platinum, platinum 10 per cent rhodium thermocouple connected a Leeds & Northrup thermocouple potentiometer.

The AC_1 and the AR_1 points are marked on each of the heating a cooling curves, respectively. The chemical analysis of each stee also given and the influence of nickel is clearly shown in steels "A "B," and "D" in lowering and separating the AC_1 and AR_1 points



FORGED STEEL "A"

C=0.34 MN=0.663 SI=0.254 P=0.014 S=0.026 NI=2.44

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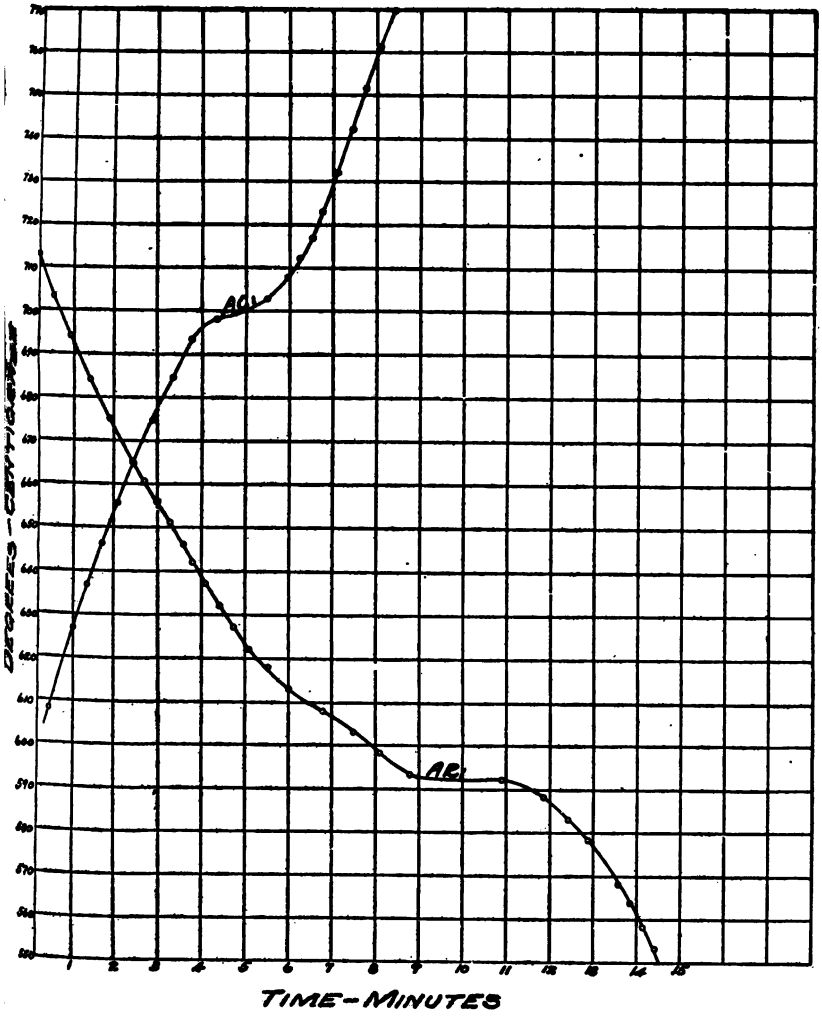

FORGED STEEL 'B'

C=0.87 MN=0.636 SI=0.210 P=0.038 S=0.025 NI=.311

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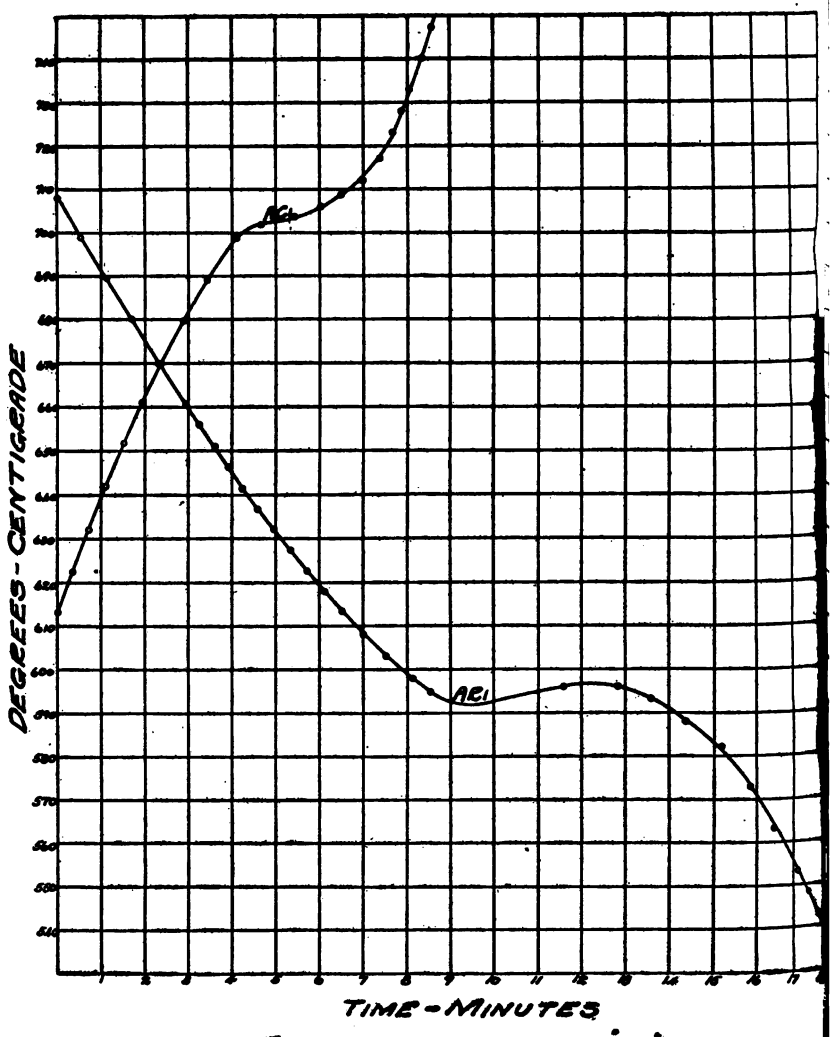

FORGED STEEL 'D'

C=0.43 MN=0.67 Si=0.185 P=0.012 S=0.032 Ni=2.5%

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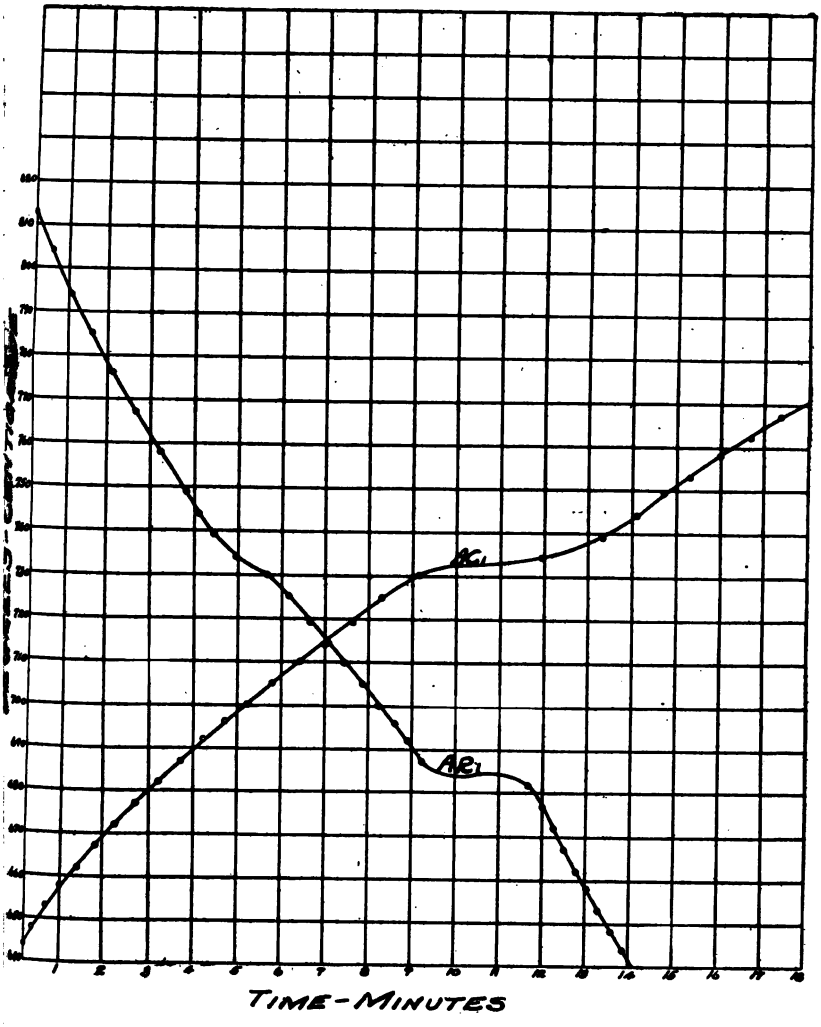

FORGED STEEL NO. 2.

C=0.394 MN=0.58 SI=0.211 P=0.017 S=0.034

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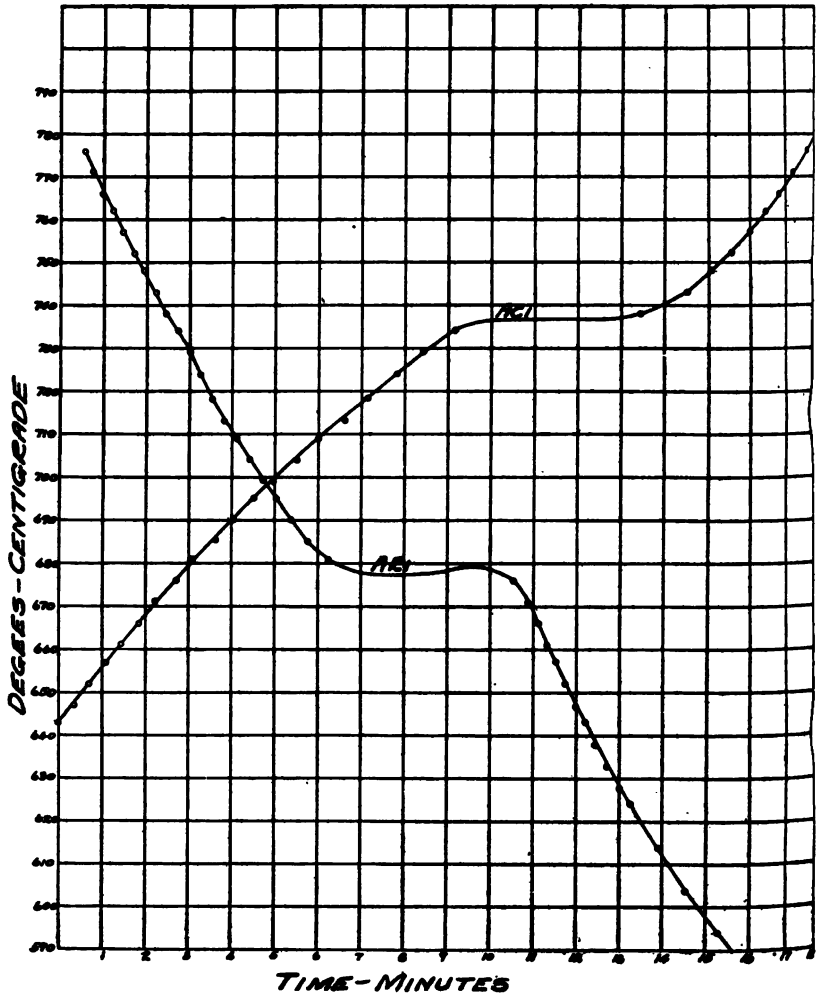

FORGED STEEL No. 3

C=0.61 Mn=0.75 Si=0.13 P=0.045 S=0.05

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TEST OF TOOL STEELS.

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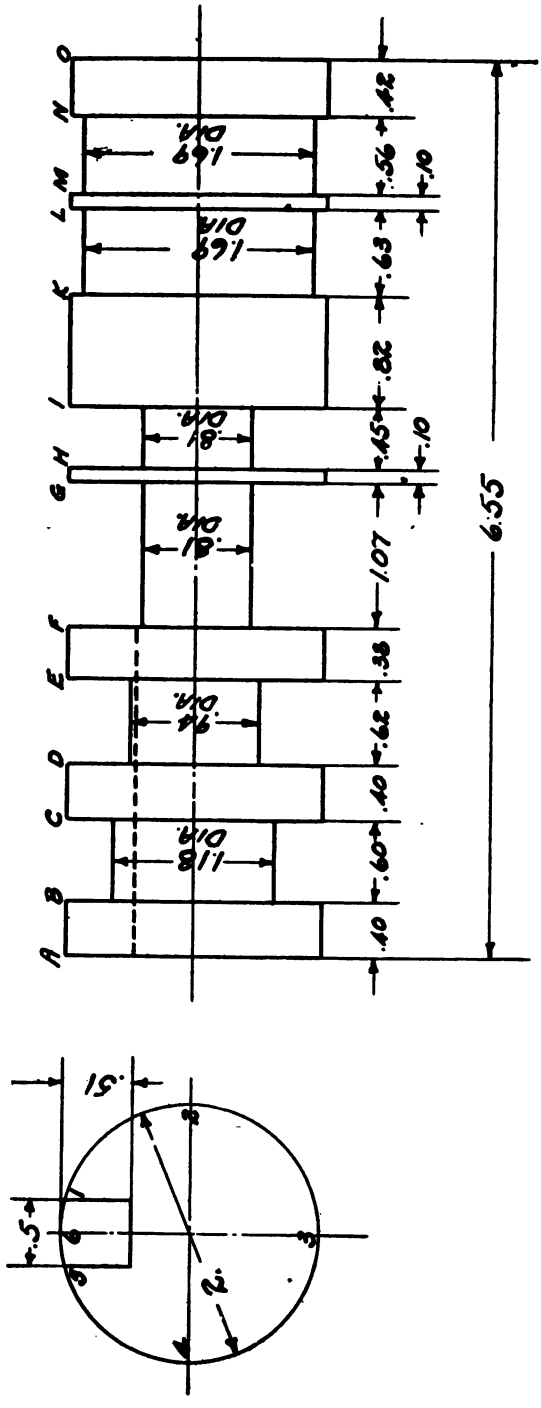

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TEST OF TOOL STEELS TO DETERMINE THE AMOUNT OF DISTORTION CAUSED BY HARDENING.

Specimens of six different steels were tested, marked "R," "S," "T," "U," "V," and "W." These steels in the annealed condition had the following physical properties:

Specimen.	Elastic limit.	Tensile strength.	Elongation.	Contraction.
	Lbs. per sq. inch.	*Lbs. per sq. inch.*	*Per cent.*	*Per cent.*
R	55,000	88,430	30.5	46.2
S	54,500	90,270	28.0	46.2
T	20,000 (?)	88,260	22.0	27.4
U	60,000	91,290	31.0	64.7
V	61,500	96,500	27.5	43.3
W	58,500	104,000	25.5	46.2

The form of the specimens used for hardening is shown in Fig. 1. Each was heated in a muffle furnace and hardened according to directions received from the manufacturer.

Micrometer measurements of each specimen were taken before and after hardening. The longitudinal measurements were taken along the perpendicular diameters 3–6 and 2–4 where possible and in other cases at points 1 & 5. Measurements of the diameters were also taken at these points.

Measurements to determine the deformation in the axial diameter were taken with an Ames dial attached to the tool post of a lathe in which the specimen was placed, and readings were taken at the points 1, 3, 4, and 6, or where necessary at 1 on collars CD, GH, and IK. The zero reading of the dial was taken at point 1 on collar NO. The various measurements are given in the tables following:

Specimen R.

MEASUREMENTS ALONG LENGTHS, INCHES.

Points.	AD.		AF.		AH.		AK.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
.....	1.388	1.392	2.388	2.388	3.544	3.538	4.821	4.815
.....	1.388	1.392	2.388	2.390	3.544	3.543	4.820+	4.820
.....	1.388	1.392	2.388+	2.392	3.544	3.550	4.820+	4.827
.....	1.387+	1.391	2.388	2.390	3.543+	3.543	4.819+	4.820
.....	1.388	1.391	2.388	2.388	3.544	3.539	4.820	4.816
Average.....	1.388	1.392	2.388	2.390	3.544	3.543	4.820	4.820
Change.....	.....	+.004	.....	+.002	.....	−.001	.....	0.

Points.	AM.		AO.		OC.		OE.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
.....	5.548+	5.542	6.546	6.538	5.561+	5.552	4.530	4.523
.....	5.548	5.546	6.546	6.544	5.561+	5.556	4.530	4.526
.....	5.548	5.554	6.547	6.553	5.561+	5.566	4.530	4.533
.....	5.547+	5.549	6.545	6.548	5.561	5.564	4.530	4.532
.....	5.548	5.544	6.546	6.541	5.561+	5.570	4.530	4.527
.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	5.548	5.547	6.546	6.544	5.561	5.562	4.530	4.528
Change.....	.....	−.001	.....	−.002	.....	+.001	.....	−.002

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Specimen R—Continued.

MEASUREMENTS ALONG LENGTHS, INCHES—Continued.

Points.	OG.		OI.		OL.	
	Before.	After.	Before.	After.	Before.	After.
1					1.098+	
2	3.094	3.093	2.553	2.552	1.098+	L
3	3.094+	3.096	2.554	2.555	1.098	L
4	3.094+	3.097	2.554	2.555	1.098	L
5						
6	3.094	3.095	2.554	2.552	1.098	L
Average	3.094	3.095	2.554	2.554	1.098	L
Change		+.001		0.		

MEASUREMENT OF DIAMETERS, INCHES.

Diameter.	FG.		HI.		KL.		MN.		NO.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	Aft
3-6	0.805	0.806	0.813	0.814	1.689	1.691+	1.688	1.689+	1.881	L
2-4	.805	.806	.813	.814	1.689	1.690	1.688+	1.690	1.881	L
Change		+.001		+.001		+.002		+.001		+

DIAL INDICATOR READINGS ON COLLAR.

Points.	CD.		IH.		IK.	
	Before.	After.	Before.	After.	Before.	After.
2	+0.0002	−0.0010	+0.0010	−0.0020	+0.0008	−0.
3	−0.0002	+0.0040	+0.0003	+0.0077	+0.0004	+0.
4	−0.0012	0.	−0.0002	+0.0030	+0.0001	+0.
6			+0.0003	−0.0065	+0.0002	−0.
1	0.	−0.0035				

Specimen S.

MEASUREMENTS ALONG LENGTHS, INCHES.

Points.	AD.		AF.		AH.		AK.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1	1.389	1.391	2.387	2.387	3.544	3.544	4.820	4.
2	1.389+	1.392	2.387	2.392	3.544	3.551	4.820	4.
3	1.390	1.395	2.387+	2.397	3.544	3.560	4.820	4.
4	1.390	1.393	2.387+	2.393	3.544	3.551	4.820	4.
5	1.390	1.392	2.388	2.388	3.544	3.545	4.820	4.
Average	1.390	1.393	2.387	2.391	3.544	3.550	4.820	4.
Change		+.003		+.004		+.006		+.

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Specimen S—Continued.

MEASUREMENTS ALONG LENGTHS, INCHES—Continued.

Points.	AM.		AO.		OC.		OE.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
	5.551	5.551	6.547	6.550	5.562	5.565	4.530	4.534
	5.550	5.558	6.547	6.557	5.562	5.570	4.530+	4.536
	5.551	5.566	6.548	6.565	5.562	5.573	4.530	4.537
	5.550+	5.558	6.547+	6.557	5.562	5.572	4.530+	4.536
	5.551	5.552	6.548	6.552	5.562	5.565	4.530+	4.535
Average	5.551	5.557	6.547	6.556	5.562	5.569	4.530	4.536
Change		+.006		+.009		+.007		+.006

Points.	OG.		OI.		OL.	
	Before.	After.	Before.	After.	Before.	After.
	3.096	3.101	2.555	2.559	1.100	1.100
	3.096	3.099	2.555	2.559	1.099+	1.100
	3.095+	3.101	2.555	2.560	1.099+	1.100
	3.096	3.101	2.555	2.559	1.099+	1.099
Average	3.096	3.101	2.555	2.559	1.099	1.100
Change		+.005		+.004		+.001

MEASUREMENT OF DIAMETERS, INCHES.

Diameter.	FG.		HI.		KL.		MN.		NO.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
	0.805	0.807	0.811	0.811+	1.688	1.689	1.688	1.689	1.879	1.880+
	.805	.806+	.811−	.811	1.688	1.689	1.688	1.690	1.879	1.880+
Change		+.002		0.		+.001		+.001		+.001

DIAL INDICATOR READINGS ON COLLAR.

Points.	CD.		GH.		IK.	
	Before.	After.	Before.	After.	Before.	After.
	+0.0039	+0.0055	+0.0028	+0.0043	+0.0019	+0.0030
	+0.0040	+0.0121	+0.0024	+0.0105	+0.0020	+0.0077
	+0.0040	+0.0049	+0.0029	+0.0026	+0.0022	+0.0020
			+0.0023	−0.0036	+0.0022	−0.0021
	+0.0041	+0.0003				

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Specimen T.

MEASUREMENTS ALONG LENGTHS, INCHES.

Points.	AD.		AF.		AH.		AK.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1	1.388	1.388	2.387	2.387	3.544	3.543	4.820	4.818
2	1.388	1.390	2.388	2.389	3.544+	3.547	4.820+	4.822
3	1.388	1.390	2.388	2.391	3.545	3.550	4.820	4.826
4	1.388	1.389	2.387+	2.390	3.544	3.546	4.819	4.822
5	1.388	1.389	2.388	2.386	3.544	3.542	4.820	4.820
Average	1.388	1.389	2.388	2.389	3.544	3.546	4.820	4.822
Change		+.001		+.001		+.002		+.002

Points.	AM.		AO.		OC.		OE.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1	5.550	5.548	6.548	6.546	5.564	5.564	4.533	4.533
2	5.550+	5.553	6.548	6.550	5.564	5.566	4.533+	4.534
3	5.550	5.557	6.548	6.555	5.564	5.570	4.533	4.537
4	5.549	5.553	6.548	6.551	5.564	5.568	4.533	4.535
5	5.550	5.549	6.548	6.547	5.564	5.565	4.533+	4.534
6								
Average	5.550	5.552	6.548	6.550	5.564	5.567	4.533	4.535
Change		+.002		+.002		+.003		+.002

Points.	OG.		OI.		OL.	
	Before.	After.	Before.	After.	Before.	After.
1						
2	3.096	3.096+	2.556	2.557	1.100+	1.100
3	3.096	3.097	2.556	2.558	1.100	1.099
4	3.095+	3.097	2.556	2.557	1.100+	1.100
5						
6	3.096	3.096	2.556	2.557	1.100	1.100
Average	3.096	3.097	2.556	2.557	1.100	1.100
Change		+.001		+.001		0.

MEASUREMENT OF DIAMETERS, INCHES.

Diameter.	FG.		HI.		KL.		MN.		NO.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
3-6	0.805	0.805	0.810	0.810	1.689	1.689	1.689	1.689	1.878	1.878
2-4	.805	.805	.810	.810	1.689	1.689	1.689	1.689	1.878	1.878
Change		0.		0.		0.		0.		0.

DIAL INDICATOR READINGS, ON COLLAR.

Points.	CD.		GH.		IK.	
	Before.	After.	Before.	After.	Before.	After.
2	+0.0017	+0.0010	+0.0018	0.	+0.0010	+0.0010
3	+0.0022	+0.0052	+0.0020	+0.0049	+0.0019	+0.0054
4	+0.0024	+0.0044	+0.0030	+0.0041	+0.0030	+0.0042
6			+0.0011	−0.0012	+0.0020	0.
1	+0.0014	+0.0010				

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Specimen U.

MEASUREMENTS ALONG LENGTHS, INCHES.

Points.	AD.		AF.		AH.		AK.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1	1.391	1.391+	2.388	2.387	3.548	3.543	4.822	4.818
2	1.391	1.394	2.390	2.394	3.548	3.551	4.823	4.826
3	1.390	1.396	2.390	2.399	3.547+	3.558	4.822	4.834
4	1.390+	1.394	2.390	2.394	3.547+	3.551	4.822	4.827
5	1.391	1.392	2.388	2.386	3.548	3.543	4.822+	4.820
Average	1.391	1.392	2.389	2.394	3.548	3.549	4.822	4.825
Change		+.001		+.005		+.001		+.003

Points.	AM.		AO.		OC.		OE.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1	5.549	5.548	6.547	6.547	5.562	5.562+	4.529	4.533
2	5.550	5.557	6.547+	6.555	5.562	5.568	4.529+	4.535
3	5.549	5.565	6.547	6.562	5.562	5.572	4.529	4.536
4	5.549+	5.558	6.547	6.555	5.562	5.568	4.529	4.534
5	5.550	5.548	6.547	6.547	5.562	5.562	4.529+	4.533
6								
Average	5.549	5.555	6.547	6.553	5.562	5.566	4.529	4.534
Change		+.006		+.006		+.004		+.005

Points.	OG.		OI.		OL.	
	Before.	After.	Before.	After.	Before.	After.
1						
2	3.092	3.098	2.548	2.555	1.098	1.100
3	3.092	3.098+	2.548	2.555	1.098	1.100
4	3.092	3.098	2.548	2.555	1.098	1.099
5						
6	3.092	3.098	2.548	2.555	1.098	1.099+
Average	3.092	3.098	2.548	2.555	1.098	1.100
Change		+.006		+.007		+.002

MEASUREMENT OF DIAMETERS, INCHES.

Diameter.	FG.		HI.		KL.		MN.		NO.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1-6	0.805	0.806	0.810	0.811	1.689	1.691	1.688	1.691	1.882	1.885
2-4	.805	.806	.810	.811	1.689	1.691	1.688	1.690	1.882	1.885
Change		+.001		+.001		+.002		+.002		+.003

DIAL INDICATOR READINGS, ON COLLAR.

Points.	CD.		GH.		IK.	
	Before.	After.	Before.	After.	Before.	After.
2	+0.0013	+0.0019	+0.0019	+0.0023	+0.0010	+0.0012
3	−0.0010	+0.0066	+0.0003	+0.0072	0.	+0.0048
4	−0.0002	+0.0003	+0.0005	+0.0015	0.	+0.0002
6			+0.0013	−0.0034	+0.0011	−0.0003
1	+0.0022	−0.0011				

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CONCLUSIONS.

From the average of the measurements AO it will be seen that all the specimens except R increased in length over all. Specimen R decreased 0.002 inch, while the increments varied as follows:

W 0.001 in.
V 0.002 in.
T 0.002 in.
U 0.006 in.
S 0.009 in.

From the inspection of the other measurements it will be seen that specimen W showed the least deformation. This is true of the variation in axial diameter as well as the change in longitudinal measurements. Specimens T, V, and R showed about equal deformations, not excessive, while specimens U and S showed deformations much greater than any of the others.

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SQUARE STEEL WIRE.

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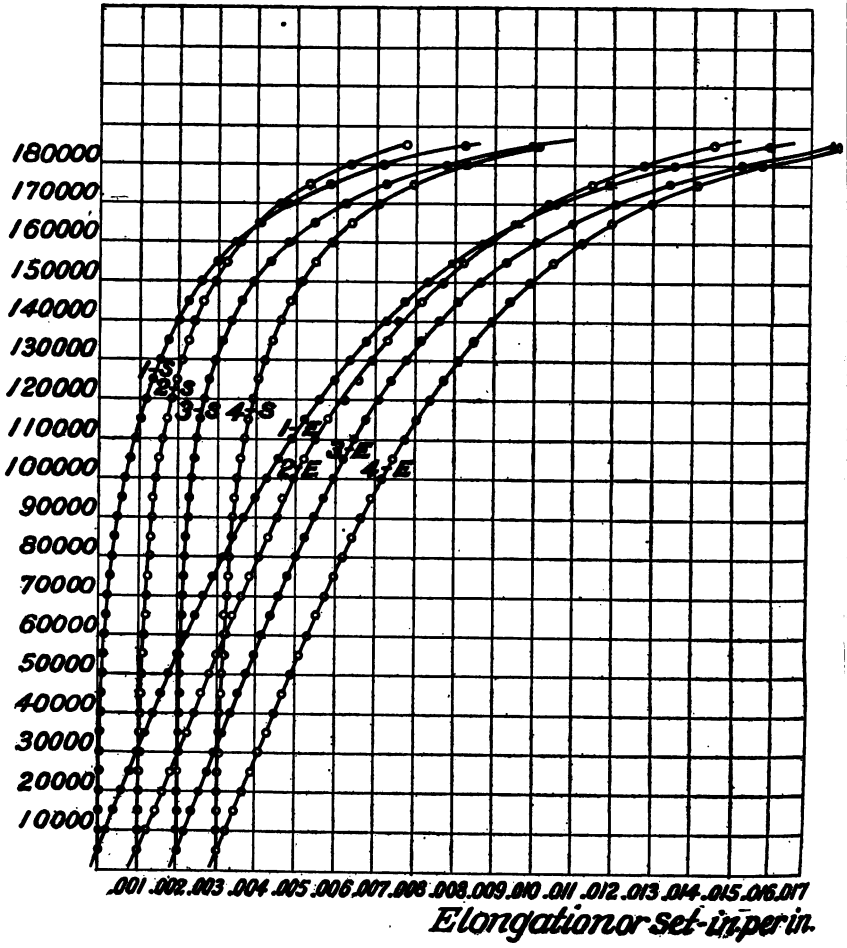

Fig. 1.

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TESTS TO DETERMINE THE EFFECT OF THE STRAIGHTENING RECEIVED BY THE WIRE WHILE PASSING THROUGH THE WIRE-WINDING MACHINE.

The specimens were designated as follows:

B, C, and D: Wire direct from the reel.

E, F, G, and H: Wire which had passed through the winding machine but had not been wound on the gun.

I, J, K, and L: Wire which had been wound on a tube 30.75 in. in diameter.

M, N, O, and P: Wire which had been wound on a tube 10⅝ in. in diameter.

All specimens from E to P inclusive, had been subjected to a winding tension of 55,000 lbs. per sq. in. All the specimens were tested without straightening, except that the ends were straightened as much as was necessary in order to place the specimen in the machine.

Average values only are plotted in Fig. 1. Curve 1–S is the mean curve of the sets of B, C, and D; and 1–E is the similar mean curve of elongation of the same specimens. Similarly, 2–S and 2–E are the mean curves for E, F, G, and H; 3–S and 3–E for I, J, K, and L; and 4–S and 4–E for M, N, O, and P.

Marks, B, C, and D.
Dimensions, 0.1260 by 0.1262 in.
Sectional area, 0.015901 sq. in.
Gauged length, 20 in.

Load (lb. per sq. in.).	Per inch.							
	Elongation, inches.				Set, inches.			
	"B"	"C"	"D"	Average.	"B"	"C"	"D"	Average.
5,000					0.			
10,000	0.00017	0.00020	0.00023	0.00020	0.	0.00001	0.00001	0.00001
15,000	.00035	.00039	.00045	.00039	0.	.00002	.00001	.00001
20,000	.00056	.00057	.00063	.00058	−.00001	.00002	.00005	.00002
25,000	.00080	.00078	.00083	.00080	−.00001	.00004	.00005	.00003
30,000	.00100	.00095	.00101	.00098	.00001	.00005	.00005	.00003
35,000	.00121	.00116	.00120	.00119	.00001	.00005	.00007	.00004
40,000	.00142	.00135	.00140	.00139	.00005	.00007	.00009	.00007
45,000	.00160	.00153	.00160	.00157	.00009	.00009	.00010	.00009
50,000	.00180	.00174	.00179	.00177	.00010	.00010	.00010	.00010
55,000	.00201	.00195	.00201	.00199	.00014	.00013	.00014	.00013
60,000	.00223	.00217	.00222	.00220	.00016	.00015	.00015	.00015
65,000	.00245	.00239	.00245	.00243	.00021	.00017	.00020	.00019
70,000	.00267	.00261	.00268	.00265	.00025	.00017	.00024	.00022
75,000	.00290	.00285	.00291	.00288	.00030	.00026	.00029	.00028
80,000	.00315	.00311	.00315	.00313	.00036	.00030	.00034	.00033
85,000	.00338	.00335	.00342	.00338	.00043	.00038	.00038	.00039
90,000	.00365	.00365	.00368	.00366	.00043	.00048	.00049	.00046
95,000	.00396	.00393	.00400	.00396	.00058	.00055	.00060	.00057
100,000	.00421	.00421	.00428	.00423	.00065	.00062	.00068	.00065
105,000	.00446	.00454	.00458	.00452	.00077	.00077	.00080	.00078
110,000	.00483	.00485	.00491	.00486	.00090	.00089	.00091	.00090
115,000	.00517	.00520	.00524	.00520	.00101	.00103	.00105	.00103
120,000	.00551	.00560	.00560	.00557	.00116	.00118	.00120	.00118
125,000	.00590	.00598	.00595	.00594	.00131	.00135	.00135	.00133
130,000	.00631	.00638	.00634	.00634	.00149	.00155	.00154	.00152
135,000	.00671	.00682	.00675	.00676	.00170	.00176	.00175	.00173
140,000	.00714	.00744	.00723	.00727	.00192	.00210	.00199	.00200
145,000	.00762	.00790	.00768	.00773	.00212	.00237	.00227	.00225
150,000	.00814	.00847	.00830	.00830	.00242	.00270	.00260	.00257
155,000	.00874	.00910	.00892	.00892	.00278	.00312	.00300	.00296
160,000	.00941	.00995	.00974	.00970	.00318	.00365	.00354	.00345
165,000	.01014	.01089	.01050	.01051	.00369	.00433	.00410	.00404
170,000	.01109	.01208	.01150	.01155	.00435	.00524	.00480	.00479
175,000	.01206	.01375	.01290	.01290	.00500	.00656	.00588	.00581
180,000	.01345	.01575	.01445	.01455	.00625	.00817	.00713	.00718
185,000	.01548	.01882	.01660	.01696	.00777	.01090	.00906	.00924

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	Tensile strength (lb. per sq. in.).	Elongation after fracture.	Dimensions at fracture.
B....	197,400	0.60 in. in 20 in.=3.0 per cent.	0.0968×0.0971 in.
C....	193,200	0.50 in. in 20 in.=2.5 per cent.	0.0968×0.0967 in.
D....	195,000	0.62 in. in 20 in.=3.1 per cent.	0.0934×0.0962 in.

	Sectional area.	Contraction of area.	Position of fracture.
	Sq. in.	*Per cent.*	
B....	0.0094	40.9	1.35 in. inside gauge marks.
C....	.0093	41.4	6.37 in. inside gauge marks.
D....	.0089	44.0	7.00 in. inside gauge marks.

Appearance of fracture:
B. Silky.
C. Fine silky, cup shaped.
D. Fine silky, cup shaped.

Marks, E, F, G, and H.
Dimensions, 0.1260 x 0.1262 in.
Sectional area, 0.015901 sq. in.
Gauged length, 15 in.

Load (lb. per sq. in.).	Per inch.									
	Elongation, inches.					Set, inches.				
	"E."	"F."	"G."	"H."	Average.	"E."	"F."	"G."	"H."	Average.
5,000	0.00022					0.000				
10,000	.00022	0.00032	0.00019	0.00017	0.00022	.00002	−0.00001	−0.00001	0.	0.
15,000	.00041	.00062	.00039	.00038	.00045	0.	0.	− .00001	0.	0.
20,000	.00061	.00086	.00055	.00054	.00064	.00004	.00005	0.	0.	.00002
25,000	.00080	.00105	.00075	.00073	.00083	−.00001	.00009	0.	0.	.00002
30,000	.00095	.00127	.00093	.00090	.00101	.00006	.00014	0.	.00001	.00005
35,000	.00122	.00147	.00113	.00110	.00123	.00005	.00014	.00003	.00001	.00005
40,000	.00139	.00168	.00133	.00131	.00142	.00006	.00020	0.	.00005	.00007
45,000	.00153	.00186	.00151	.00149	.00159	.00006	.00021	0.	.00005	.00008
50,000	.00174	.00208	.00171	.00169	.00180	.00006	.00025	.00005	.00007	.00010
55,000	.00191	.00227	.00190	.00190	.00199	.00007	.00026	.00007	.00009	.00012
60,000	.00213	.00250	.00208	.00213	.00221	.00007	.00029	.00007	.00024	.00016
65,000	.00233	.00267	.00232	.00227	.00239	.00008	.00031	.00009	.00029	.00019
70,000	.00253	.00290	.00249	.00251	.00260	.00010	.00033	.00012	.00031	.00021
75,000	.00274	.00313	.00269	.00273	.00282	.00013	.00039	.00012	.00033	.00024
80,000	.00299	.00338	.00299	.00294	.00307	.00014	.00042	.00018	.00037	.00028
85,000	.00319	.00359	.00319	.00316	.00328	.00017	.00046	.00020	.00037	.00030
90,000	.00346	.00382	.00340	.00339	.00351	.00021	.00052	.00025	.00041	.00034
95,000	.00371		.00365	.00365	.00367	.00028		.00031	.00046	.00035
100,000	.00395	Run by	.00393	.00389	.00392	.00033	Run by	.00042	.00051	.00042
105,000	.00421	through	.00419	.00414	.00418	.00039	through	.00055	.00058	.00050
110,000	.00452	error.	.00448	.00443	.00447	.00047	error.	.00068	.00065	.00060
115,000	.00481		.00479	.00475	.00478	.00055		.00081	.00074	.00070
120,000	.00513	.00553	.00527	.00501	.00523	.00063	.00100	.00081	.00081	.00081
125,000	.00548	.00587	.00561	.00537	.00558	.00080	.00113	.00093	.00094	.00095
130,000	.00584	.00619	.00599	.00569	.00592	.00092	.00125	.00111	.00109	.00109
135,000	.00623	.00656	.00634	.00610	.00630	.00106	.00139	.00126	.00125	.00124
140,000	.00661	.00695	.00681	.00650	.00659	.00125	.00155	.00144	.00130	.00140
145,000	.00707	.00738	.00721	.00699	.00716	.00146	.00171	.00167	.00164	.00162
150,000	.00758	.00790	.00787	.00751	.00771	.00173	.00215	.00201	.00198	.00195
155,000	.00809	.00836	.00835	.00807	.00821	.00202	.00227	.00231	.00225	.00221
160,000	.00863	.00898	.00911	.00865	.00884	.00235	.00261	.00274	.00259	.00257
165,000	.00937	.00966	.00991	.00939	.00958	.00277	.00300	.00326	.00305	.00302
170,000	.01012	.01045	.01072	.01020	.01037	.00331	.00353	.00383	.00359	.00355
175,000	.01120	.01139	.01187	.01139	.01146	.00403	.00416	.00469	.00441	.00432
180,000	.01240	.01271	.01335	.01265	.01277	.00490	.00517	.00581	.00547	.00533
185,000	.01407	.01437	.01550	.01420	.01453	.00630	.00652	.00761	.00689	.00677

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	Tensile strength (lb. per sq. in.).	Elongation after fracture.	Dimensions at fracture.
E.	199,250	0.45 in. in 15 in.=3.0 per cent.	0.0943 x 0.0951 in.
F.	199,580	0.42 in. in 15 in.=2.8 per cent.	0.0950 x 0.0952 in.
G.	197,640	0.39 in. in 15 in.=2.6 per cent.	0.0960 x 0.0963 in.
H.	196,740	0.42 in. in 15 in.=2.8 per cent.	0.0946 x 0.0955 in.

	Sectional area.	Contraction of area.	Position of fracture.
	Sq. in.	*Per cent.*	
E.	0.00897	43.6	6.25 in. inside gauge marks.
F.	0.00904	43.1	1.00 in. outside of gauge marks.
G.	0.00924	41.8	2.75 in. inside gauge marks.
H.	0.00903	43.2	4.30 in. inside gauge marks.

Appearance of fracture:
E. Fine silky.
F. Fine silky.
G. Fine silky.
H. Fine silky, cup shaped.

Marks, I, J, K, and L.
Dimensions, 0.1260 x 0.1262 in.
Sectional area, 0.015901 sq. in.
Gauged length, 15 in.

Load (lb. per sq. in.).	Per inch.									
	Elongation, inches.					Set, inches.				
	I.	J.	K.	L.	Average.	I.	J.	K.	L.	Average.
5,000										
10,000	0.00020	0.00020	0.00021	0.00015	0.00019	0.	−0.00005	0.	0.00001	0.
15,000	.00038	.00039	.00040	.00027	.00036	0.	− .00005	.00001	.00001	0.
20,000	.00058	.00060	.00060	.00046	.00056	0.	− .00001	.00002	.00002	0.
25,000	.00077	.00079	.00079	.00066	.00075	.00001	0.	.00005	0.	.00001
30,000	.00093	.00101	.00098	.00082	.00093	.00002	.00001	.00006	.00001	.00002
35,000	.00114	.00121	.00119	.00100	.00113	0.	.00004	.00007	−.00001	.00002
40,000	.00134	.00141	.00138	.00123	.00134	.00001	.00005	.00008	.00004	.00004
45,000	.00154	.00161	.00155	.00141	.00152	.00006	.00006	.00008	.00006	.00006
50,000	.00176	.00181	.00175	.00161	.00173	.00007	.00007	.00008	.00008	.00007
55,000	.00199	.00201	.00197	.00181	.00194	.00008	.00008	.00011	.00008	.00008
60,000	.00213	.00221	.00215	.00200	.00212	.00010	.00011	.00012	.00008	.00010
65,000	.00235	.00245	.00239	.00221	.00235	.00011	.00013	.00013	.00008	.00011
70,000	.00258	.00264	.00257	.00241	.00255	.00012	.00015	.00015	.00009	.00012
75,000	.00280	.00287	.00278	.00263	.00277	.00015	.00020	.00017	.00011	.00015
80,000	.00301	.00307	.00298	.00282	.00297	.00018	.00021	.00019	.00013	.00017
85,000	.00325	.00329	.00320	.00307	.00320	.00020	.00025	.00021	.00015	.00020
90,000	.00347	.00353	.00345	.00332	.00344	.00026	.00028	.00025	.00021	.00025
95,000	.00373	.00378	.00367	.00353	.00367	.00031	.00034	.00028	.00022	.00028
100,000	.00397	.00402	.00391	.00379	.00392	.00037	.00039	.00032	.00027	.00033
105,000	.00425	.00430	.00414	.00401	.00417	.00045	.00048	.00036	.00032	.00040
110,000	.00454	.00459	.00441	.00429	.00445	.00053	.00059	.00041	.00035	.00047
115,000	.00486	.00489	.00467	.00459	.00475	.00065	.00067	.00045	.00044	.00055
120,000	.00521	.00522	.00493	.00491	.00506	.00079	.00078	.00051	.00054	.00065
125,000	.00555	.00559	.00521	.00527	.00540	.00093	.00092	.00059	.00067	.00077
130,000	.00598	.00597	.00548	.00567	.00577	.00108	.00109	.00071	.00085	.00093
135,000	.00637	.00640	.00575	.00605	.00614	.00128	.00131	.00085	.00104	.00112
140,000	.00687	.00685	.00619	.00652	.00660	.00153	.00153	.00102	.00123	.00132
145,000	.00738	.00739	.00665	.00693	.00708	.00184	.00183	.00125	.00144	.00159
150,000	.00800	.00797	.00708	.00755	.00765	.00221	.00215	.00146	.00177	.00189
155,000	.00873	.00860	.00767	.00819	.00829	.00267	.00257	.00180	.00221	.00231
160,000	.00950	.00939	.00838	.00894	.00905	.00317	.00308	.00219	.00267	.00277
165,000	.01047	.01030	.00917	.00993	.00996	.00391	.00375	.00273	.00339	.00344
170,000	.01179	.01145	.01020	.01081	.01106	.00492	.00459	.00336	.00401	.00421
175,000	.01317	.01293	.01133	.01225	.01242	.00605	.00574	.00425	.00507	.00527
180,000	.01520	.01495	.01293	.01399	.01426	.00765	.00739	.00547	.00668	.00679
185,000	.01787	.01787	.01507	.01643	.01681	.00991	.00987	.00720	.00872	.00892

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	Tensile strength (lb. per sq. in.).	Elongation after fracture.	Dimensions at fracture.
I.....	196,290	0.45 in. in 15 in.=3 per cent.....	0.0951 x 0.0954 in.
J.....	195,000	0.31 in. in 15 in.=2.1 per cent.....	0.0961 x 0.0955 in.
K.....	197,990	0.27 in. in 15 in.=1.8 per cent.....	0.0972 x 0.0961 in.
L.....	196,480	0.31 in. in 15 in.=2.07 per cent.....	0.0940 x 0.0938 in.

	Sectional area.	Contraction of area.	Position of fracture.
	Sq. in.	*Per cent.*	
I.....	0.00907	42.9	2.70 in. inside of gauge marks.
J.....	0.00917	42.3	1.50 in. outside of gauge marks.
K.....	0.00934	41.2	1.40 in. outside of gauge marks.
L.....	0.00881	44.5	1.15 in. outside of gauge marks.

Appearance of fracture:
I. Fine silky.
J. Fine silky.
K. Fine silky.
L. Fine silky.

Marks, M, N, O, and P.
Dimensions, 0.1260 x 0.1262 in.
Sectional area, 0.015901 sq. in.
Gauged length of specimens M, N, and O, 20 in.
Gauged length of specimen P, 15 in.

Load (lb. per sq. in.).	Per inch.									
	Elongation, inches.					Set, inches.				
	M.	N.	O.	P.	Average.	M.	N.	O.	P.	Average.
5,000										
10,000	0.00023	0.00024	0.00032	0.00011	0.00022	0.00001	0.00004	0.00003	−0.00008	0.
15,000	.00046	.00050	.00056	.00028	.00045	.00004	.00005	.00006	− .00010	−.00001
20,000	.00065	.00072	.00079	.00046	.00065	.00001	.00006	.00007	− .00010	.00001
25,000	.00084	.00089	.00100	.00065	.00084	.00003	.00007	.00009	− .00010	.00002
30,000	.00100	.00111	.00121	.00085	.00104	.00005	.00007	.00012	− .00008	.00004
35,000	.00127	.00132	.00141	.00114	.00128	.00006	.00009	.00014	− .00006	.00005
40,000	.00145	.00151	.00160	.00124	.00145	.00009	.00011	.00016	− .00005	.00007
45,000	.00165	.00172	.00183	.00146	.00166	.00012	.00013	.00020	− .00003	.00010
50,000	.00185	.00194	.00206	.00165	.00187	.00014	.00013	.00025	0.	.00013
55,000	.00207	.00212	.00226	.00187	.00208	.00016	.00015	.00028	.00003	.00015
60,000	.00229	.00235	.00247	.00208	.00229	.00015	.00021	.00030	.00006	.00018
65,000	.00250	.00259	.00270	.00230	.00252	.00017	.00025	.00036	.00008	.00021
70,000	.00271	.00279	.00293	.00252	.00273	.00022	.00026	.00038	.00009	.00023
75,000	.00293	.00302	.00315	.00275	.00296	.00026	.00030	.00042	.00013	.00027
80,000	.00316	.00323	.00340	.00300	.00319	.00029	.00030	.00046	.00016	.00030
85,000	.00339	.00342	.00368	.00319	.00342	.00032	.00033	.00051	.00020	.00034
90,000	.00360	.00363	.00390	.00350	.00365	.00035	.00035	.00058	.00027	.00038
95,000	.00390	.00384	.00416	.00372	.00390	.00042	.00036	.00064	.00029	.00042
100,000	.00417	.00405	.00445	.00405	.00418	.00050	.00040	.00068	.00039	.00049
105,000	.00446	.00434	.00472	.00429	.00445	.00059	.00046	.00080	.00046	.00057
110,000	.00476	.00462	.00501	.00460	.00474	.00070	.00055	.00090	.00054	.00067
115,000	.00510	.00492	.00531	.00489	.00505	.00081	.00064	.00099	.00059	.00075
120,000	.00543	.00526	.00564	.00526	.00539	.00094	.00076	.00110	.00077	.00089
125,000	.00577	.00559	.00598	.00560	.00573	.00106	.00089	.00121	.00089	.00101
130,000	.00617	.00594	.00634	.00595	.00610	.00124	.00105	.00139	.00106	.00118
135,000	.00660	.00631	.00673	.00635	.00649	.00145	.00120	.00160	.00123	.00137
140,000	.00711	.00675	.00711	.00679	.00694	.00172	.00141	.00185	.00141	.00159
145,000	.00752	.00720	.00757	.00728	.00739	.00195	.00162	.00206	.00167	.00182
150,000	.00809	.00767	.00811	.00777	.00791	.00225	.00186	.00238	.00195	.00211
155,000	.00869	.00822	.00865	.00841	.00849	.00265	.00220	.00269	.00233	.00246
160,000	.00947	.00895	.00939	.00905	.00921	.00312	.00259	.00310	.00269	.00287
165,000	.01029	.00961	.01022	.00979	.00997	.00367	.00310	.00356	.00321	.00338
170,000	.01139	.01051	.01130	.01069	.01097	.00451	.00371	.00430	.00383	.00408
175,000	.01269	.01154	.01243	.01185	.01212	.00550	.00445	.00520	.00467	.00495
180,000	.01481	.01292	.01389	.01347	.01377	.00724	.00553	.00640	.00593	.00627
185,000	.01781	.01406	.01604	.01554	.01601	.00973	.00695	.00818	.00764	.00812

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	Tensile strength (lb. per sq. in.).	Elongation after fracture.	Dimensions at fracture.
M....	195,440	0.56 in. in 20 in.=2.8 per cent.	0.0942 x 0.0935 in.
N....	197,030	0.52 in. in 20 in.=2.6 per cent.	0.0962 x 0.0963 in.
O....	195,890	0.48 in. in 20 in.=2.4 per cent.	0.0965 x 0.0960 in.
P....	196,960	0.30 in. in 15 in.=2.0 per cent	0.0968 x 0.0962 in.

	Sectional area.	Contraction of area.	Position of fracture.
	Sq. in.	*Per cent.*	
M....	0.00880	44.6	7.75 in. from one gauge mark.
N....	0.00926	41.7	1.35 in. from one gauge mark.
O....	0.00926	41.7	8.40 in. from one gauge mark.
P....	0.00931	41.4	0.25 in. from one gauge mark.

Appearance of fracture:
M. Fine silky.
N. Fine silky, cup shaped.
O. Fine silky.
P. Fine silky, cup shaped.

Tabulation.

	Tensile strength (lb. per sq. in.).	Elastic limit (lb. per sq. in.).	Per cent elongation between 20,000 and 100,000 lbs. per square inch.	Contraction of area (per cent).
Wire from reel	195,200	65,000 to 85,000	0.182	42.1
Between wire-winding machine and gun	198,630	75,000 to 100,000	0.224	42.9
From 30.75-in. cylinder	196,420	80,000 to 95,000	0.226	42.7
From 10¼-in. cylinder	196,320	80,000 to 95,000	0.191	42.4

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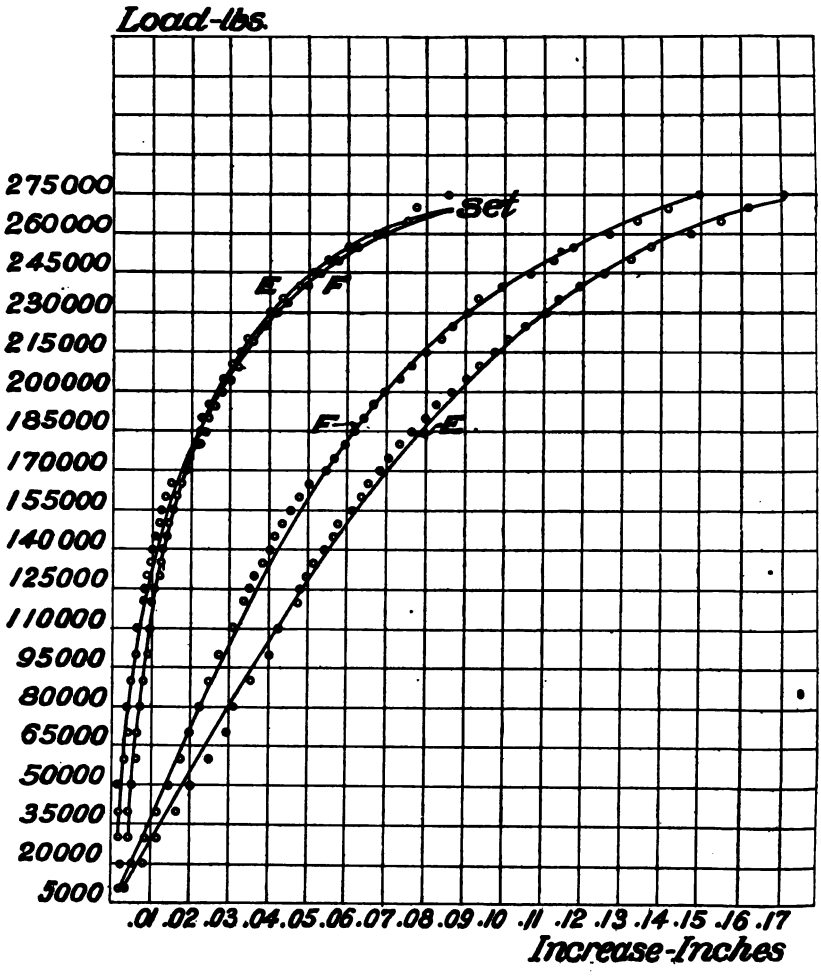

Fig. 4.

Measurements E and F with Sets.

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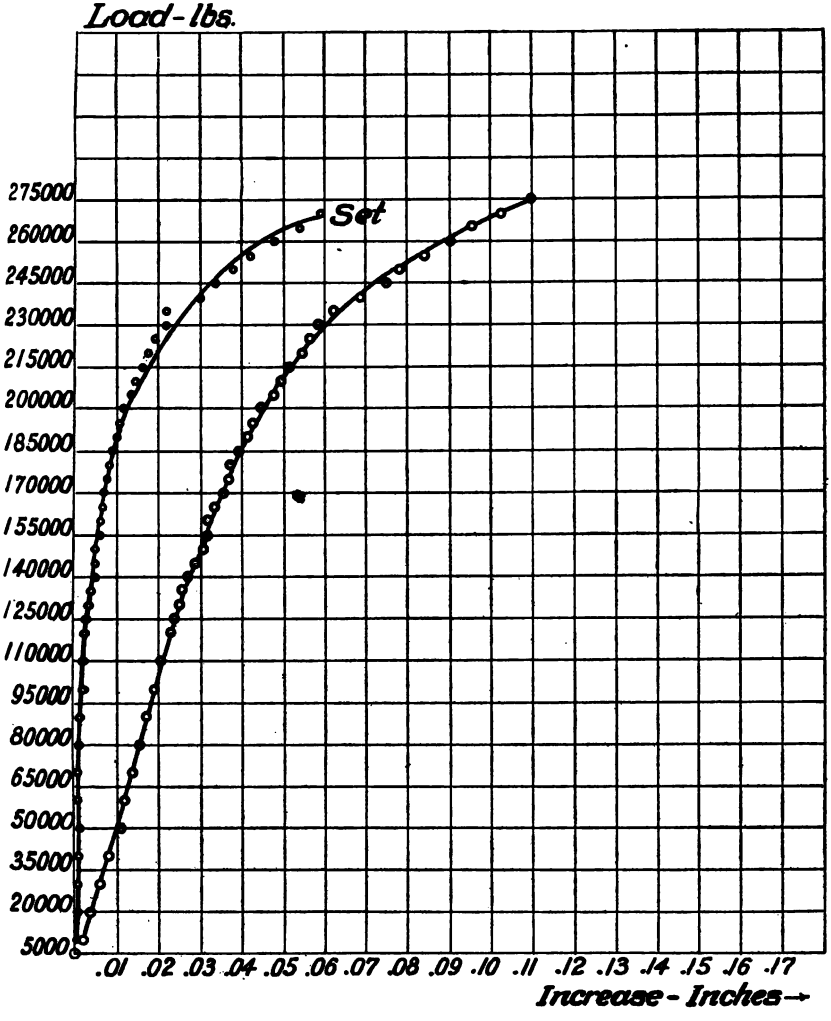

Fig. 5.

Measurement G with Set.

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ROPE FASTENINGS.

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TENSILE TESTS OF VARIOUS METHODS OF SECURING ROPE IN DETERMINING ITS TENSILE STRENGTH.

Material: 3-strand manila rope. Two coils, each one piece, were used.

	Coil "M."	Coil "N."
Diameter	0.85 in.	0.84 in.
Area of circle of above diameter	0.567 sq. in.	0.554 sq. in.
Circumference	2.68 in.	2.50 in.

Methods of fastening (see Fig. 1):

A. Eye splice, with two tucks on each strand.
B. Eye splices, with four tucks on each strand. The first two tucks made with the full section of strand. For the third about one-third of the section was cut away, and for the fourth another third. This produced a splice which tapered gradually to the diameter of the rope between the splices.
C. Special fixture.
D. Bowline knot.
E. Slip knot.
F. Two turns around pins and the ends seized to standing part.
G. Fisherman's bend.
H. Round turn and half hitch.
I. Glove hitch.

Samples taken from coil "M."

Number.	Kind of fastening.	Length of specimen.	Length between knots or ends of splices.	Length required for 2 fastenings.	Time required to make 2 fastenings.	Tensile strength. Total.	Tensile strength. Per sq. in.	Parted.
		Ft. in.	*In.*	*Ft. in.*	*Min.*	*Lb.*	*Lb.*	
1	A	5 3	18	3 9	15	4,920	8,670	1 strand at end of splice.
2	A	5 3	18	3 9	15	4,550	8,020	Do.
3	A	5 3	18	3 9	15	4,500	7,940	Do.
4	B	5 6	18	4 0	35 to 40	5,200	9,170	Do.
5	B	5 6	18	4 0	35 to 40	4,200	7,400	Do.
6	B	5 6	18	4 0	35 to 40	4,910	8,640	Do.
7	C	12 6	18	11 0	5	3,225	5,690	2 strands in the fixture.
8	C	12 6	18	11 0	5	3,080	5,430	Do.
9	C	12 6	18	11 0	5	3,120	5,500	Do.
10	D	7 6	18	6 0	4	2,400	4,230	1 strand at short bend.
11	D	7 6	18	6 0	4	2,090	3,680	Do.
12	D	7 6	18	6 0	4	2,270	4,000	2 strands at short bend.
13	E	6 6	18	5 0	3 to 5	3,380	5,960	1 strand at the bight.
14	E	6 6	18	5 0	3 to 5	3,060	5,400	1 strand at the pin.
15	E	6 6	18	5 0	3 to 5	2,856	5,030	2 strands at the pin.
16	F	6 6	18	5 0	.....	2,346	4,140	Do.
17	G	8 6	18	7 0	15 to 20	2,448	4,310	1 strand at the bight.
18	H	8 6	18	7 0	10 to 15	2,856	5,040	2 strands at the bight.
19	I	11 6	42	8 0	3	3,600	6,350	1 strand at the bight.
			Sample taken from coil "N."					
20	A	5 0	11	4 0	15	4,720	8,520	1 strand at the splice.
21	B	5 0	11	4 0	35 to 40	5,180	9,350	Do.
22	I	11 6	42	6 0	3	3,700	6,680	1 strand at the bight.

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Specimens 7, 8, and 9, special fixture, and specimens 13, 14, and 15, slip knot, slipped continuously until rupture occurred.

Specimen 16 slipped so that it was necessary to reseize the end three or four times before it held. This took about two hours after the load was applied for the first time.

The results are shown graphically in Figs. 2, 3, and 4, which warrants the conclusion that eye splices are the most satisfactory, considering the high strength which they develop in the specimen. The cost, also, is not excessive when compared with many of the fastenings which require much more rope to make. Even with the eye splices the full strength of the rope is not developed, as shown by the fact that the fracture almost always occurs at the inside end of the splice. Possibly not more than 95 per cent of the strength is developed in most cases.

The weakness of these fastenings appears to be caused by the low strength of rope at bends of small radius. This conclusion is borne out by a study of the diagrams and the strength developed by each.

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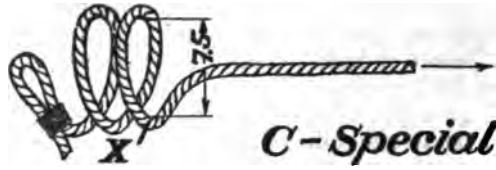
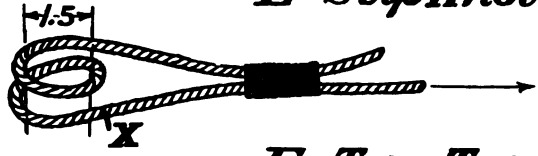


C - Special Fixture.

D - Bowline Knot.

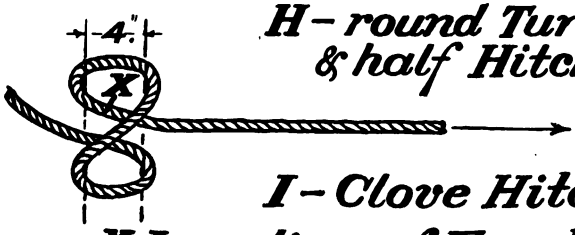
E - Slip Knot.



F - Two Turns.

G - Fisherman's Bend

H - round Turn, & half Hitch.



I - Clove Hitch.

X=Location of Fracture.

Tests of Fastenings for Rope.

Fig. 1.

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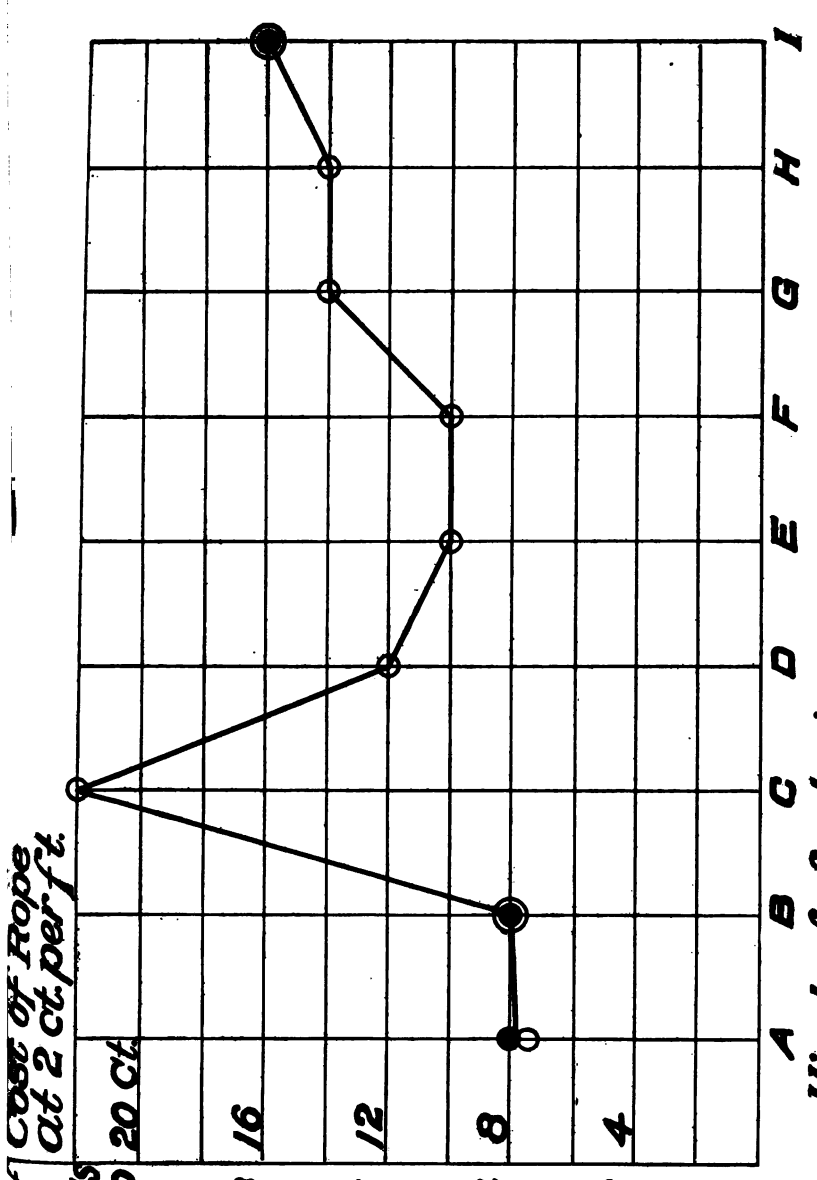

Fig. 2.

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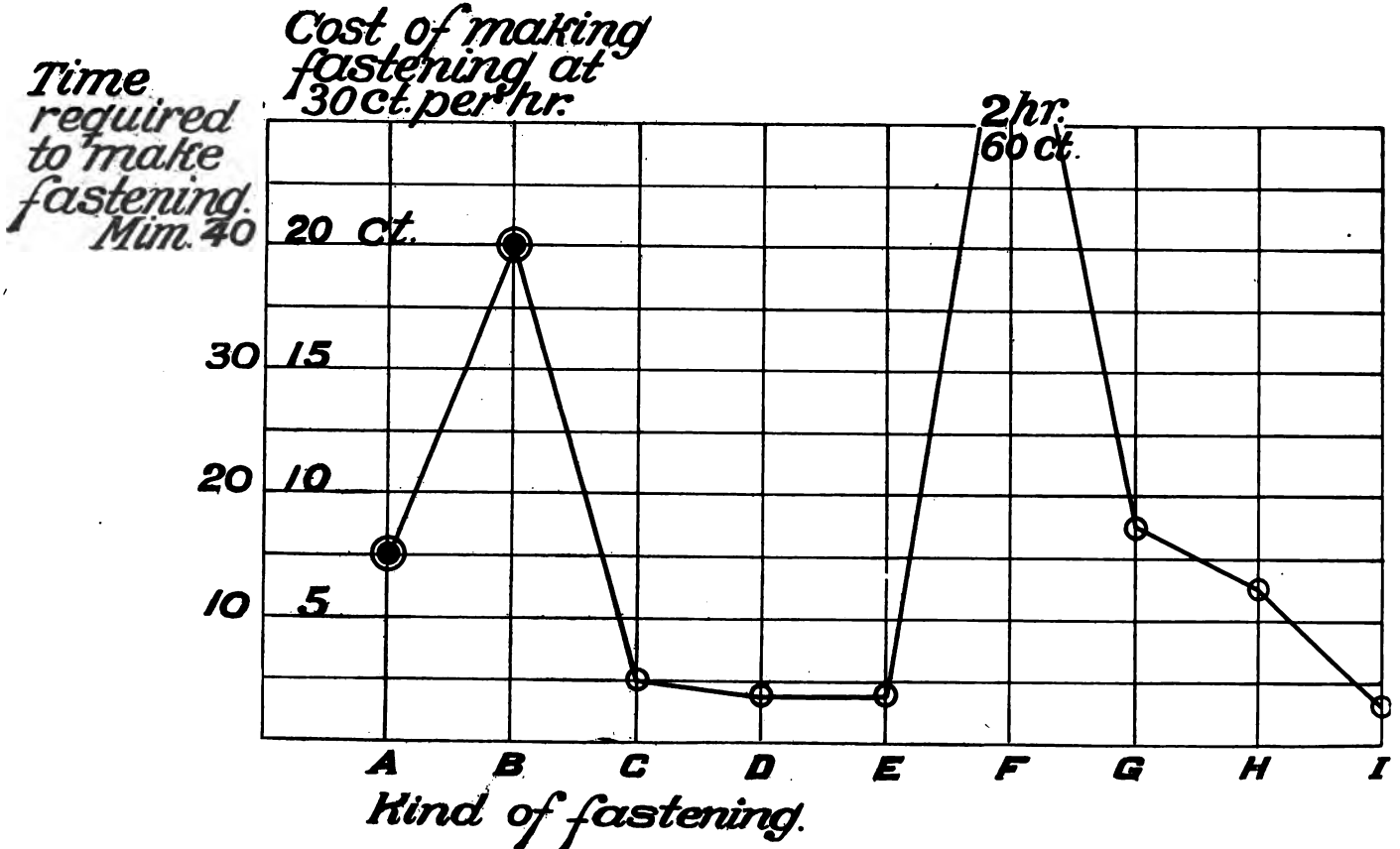

Fig. 3

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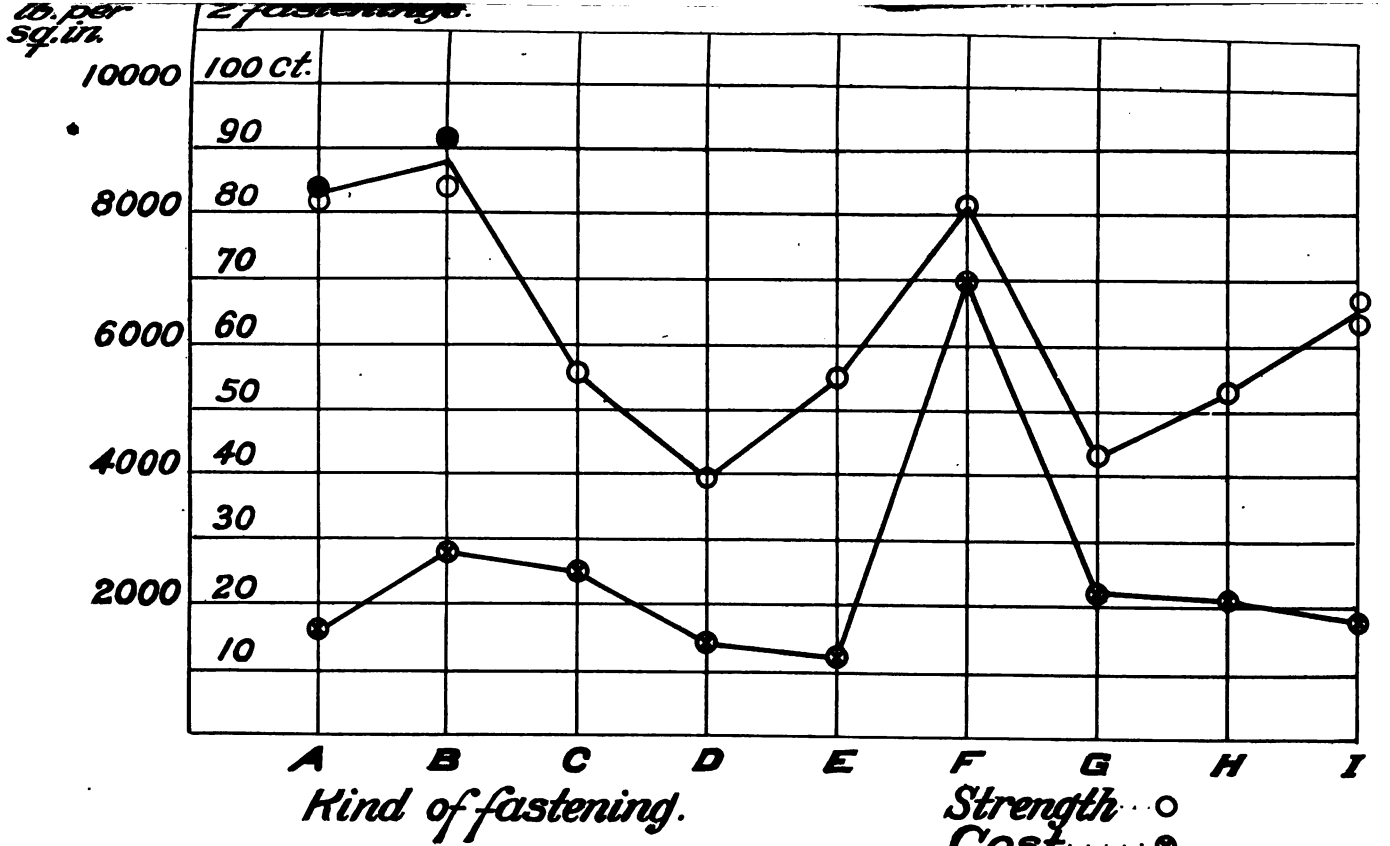

Fig. 4.

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NSILE TESTS OF STEEL SPECIMENS FOR THE PURPOSE OF STANDARDIZING TESTING MACHINES.

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Test 308.

Albert & J. M. Anderson Mfg. Co. Works, South Boston, Mass.

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.		Elongation in 8 inches.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).	Inches.	Per cent.
	In.	*Sq. in.*	*Lb.*		*Lb.*			
2	0.7980	0.50	22,032	44,064	38,148	76,296	1.90	23.8
4	.7973	.499	21,828	43,717	38,454	77,003	2.01	25.0
6	.7980	.50	22,542	45,084	38,556	77,112	1.83	22.9

Marks.	Elongation in inch sections.								Diameter at fracture.	Contraction of area.	Appearance of fracture.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*P. ct.*	
2	0.15	0.19	0.25	[1] 0.56	0.25	0.19	0.17	0.14	0.55	52.5	Fine silky.
4	.17	.21	.27	[1] .55	.25	.22	.20	.14	.54	54.1	Fine silky; cup shaped.
6	.15	.18	.23	[1] .54	.27	.17	.15	.14	.54	54.2	Fine silky.

[1] Inch section in which fracture occurred.

Test 401.

Gulick-Henderson Co., Bailey-Farrell Building, Pittsburgh, Pa.

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.		Elongation in 2 inches.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).	Inch.	Per cent.
	In.	*Sq. in.*	*Lb.*		*Lb.*			
2	0.5041	0.1995	8,976	44,990	15,198	76,180	0.54	27.0
4	.5022	.1980	8,568	43,270	14,994	75,720	.58	29.0
6	.5038	.1993	8,670	43,500	15,096	75,740	.60	30.0
8	.5000	.1963	8,466	43,120	14,688	74,820	.57	28.5
10	.5021	.1979	8,772	44,320	14,994	75,760	.57	28.5
12	.4992	.1957	8,670	44,300	14,790	75,570	.55	27.5

Marks.	Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	In.	*In.*	*In.*	*P. ct.*	
2	0.17	[1] 0.37	0.36	49.0	Fine silky.
4	[1] .39	.19	.36	48.6	Do.
6	[1] .25	[1] .35	.35	51.7	Do.
8	[1] .28	[1] .29	.37	45.2	Do.
10	[1] .41	.16	.35	51.3	Do.
12	[1] .29	[1] .26	.37	45.0	Do.

[1] Inch section in which fracture occurred.

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Test 407.

Detrick & Harvey Machine Co., Baltimore, Md.

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.		Elongation in 2 inches.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).	Inch.	Per cent.
	In.	*Sq. in.*	*Lb.*		*Lb.*			
2 C. W.	0.5058	0.2009	8,976	44,670	12,036	59,910	0.76	38.0
4 C. W.	.5058	.2009	8,364	41,630	12,036	59,910	.74	37.0

Marks.	Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	In.	*In.*	*In.*	*Per cent.*	
2 C. W.	[1] 0.39	[1] 0.37	0.32	59.9	Fine silky.
4 C. W.	[1] .48	.26	.29	67.1	Do.

[1] Inch section in which fracture occurred.

Test 445.

John A. Roebling's Sons Co., Trenton, N. J.

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).
	Inch.	*Sq. in*	*Lb.*		*Lb.*	
2.....	0.5043	0.1997	10,690	53,530	17,740	88,830
4.....	.5043	.1997	10,200	51,070	17,650	88,380
6.....	.5041	.1996	10,300	51,600	17,640	88,370
8.....	.5048	.1991	10,500	52,730	17,720	89,000
10.....	.5048	.1991	10,200	51,230	17,640	88,590

Marks.	Elongation in 2 inches.		Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	In.	*Per cent.*	*In.*	*In.*	*In.*	*Per cent.*	
2.....	0.50	25.0	[1] 0.26	0.24	0.42	30.6	Fine silky.
4.....	.52	26.0	[1] .30	.22	.41	33.8	Do.
6.....	.50	25.0	[1] .25	.25	.42	30.6	Do.
8.....	.51	25.5	[1] .26	.25	.42	30.4	Do.
10.....	.48	24.0	[1] .25	.23	.43	27.0	Do.

[1] Inch section in which fracture occurred.

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Test 387.

Isthmian Canal Commission, Panama.

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.		Elongation in 2 inches.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).	Inch.	Per cent.
	In.	*Sq. in.*	*Lb.*		*Lb.*			
1.....	0.5050	0.20	10,000	50,000	19,278	96,390	0.49	24.5
3.....	.5050	.20	9,792	48,960	19,074	95,370	.51	25.5
5.....	.5050	.20	9,690	48,450	18,870	94,350	.53	26.5
7.....	.5051	.20	9,996	49,980	19,278	96,390	.51	25.5
9.....	.5050	.20	10,098	50,490	20,094	100,470	.50	25.0
11.....	.5050	.20	10,098	50,490	20,196	100,980	.50	25.0

Marks.	Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	In.	*In.*	*In.*	*Per cent.*	
1.....	[1] 0.28	[1] 0.21	0.40	37.2	Silky.
3.....	[1].33	.18	.36	49.1	Do.
5.....	[1].35	.18	.35	51.9	Do.
7.....	.18	[1].33	.36	49.1	Do.
9.....	.20	[1].30	.35	51.9	Do.
11.....	[1].29	.21	.38	43.3	Silky trace of granulation.

[1] Inch section in which fracture occurred.

Test 471.

Carpenter Steel Co., Reading, Pa.

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.		Elongation in 2 inches.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).	Inch.	Per cent.
	In.	*Sq. in.*	*Lb.*		*Lb.*			
2	0.5053	0.2005	10,800	53,860	19,600	97,750	0.40	20.0
4	.5052	.2004	10,900	54,390	19,700	98,300	.43	21.5
6	.5050	.2003	10,700	53,410	19,600	97,850	.38	19.0
8	.5052	.2004	11,200	55,880	20,100	100,290	.39	19.5
10	.5051	.2004	11,100	55,380	20,000	99,800	.39	19.5

Marks.	Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	In.	*In.*	*In.*	*P. ct.*	
2	0.21	0.19	0.43	27.5	Fine granular 75 per cent, amorphous 25 per cent.
4	.26	.17	.42	30.8	Fine granular 40 per cent, amorphous 60 per cent.
6	.20	.18	.44	24.0	Fine granular 60 per cent, amorphous 40 per cent.
8	.28	.11	.41	34.1	Amorphous trace of granulation.
10	.22	.17	.44	24.1	Fine granular 50 per cent, amorphous 50 per cent.

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Test. 516.

The Midvale Steel Co., Philadelphia, Pa.

Marks.	Diameter.	Sectional area.	Approx. elastic limit.		Tensile strength.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).
	In.	*Sq. in.*	*Lb.*		*Lb.*	
A 1	0.5031	0.1988	16,500	82,990	20,900	105,130
A 3	.5041	.1996	16,900	84,660	21,200	106,210
A 5	.5040	.1995	17,000	85,210	21,300	106,760
B 4	.5043	.1997	16,800	84,120	21,100	105,650
B 6	.5046	.2000	17,000	85,000	21,100	105,500

Marks.	Elongation in 2 inches.		Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	In.	*P. ct.*	*In.*	*In.*	*In.*	*P. ct.*	
A 1	0.55	27.5	[1] 0.40	0.15	0.28	69.0	Fine silky, serrated.
A 3	.51	25.5	.18	[1] .33	.29	66.9	Do.
A 5	.54	27.0	.16	[1] .38	.30	64.6	Do.
B 4	.54	27.0	[1] .41	.13	.28	69.2	Do.
B 6	.53	26.5	[1] .34	.19	.29	67.0	Do.

[1] Inch section in which fracture occurred.

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CORDAGE.

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Soft braided linen line.

Diameter.	Length between fixtures.	Breaking strength.	Parted.
In.	*In.*	*Lbs.*	
0.17	24.00	324	At the fixture.
.18	20.00	324	

Manila rope (3 strand).

[Samples prepared for testing with eye splices at the ends and wet before testing.]

Nominal size.		Length of sample.	Length between splices.	Weight of sample.	Breaking length.	Circumference.	Diameter.	Sectional area.
Diameter.	Circumference.							
In.	*In.*	*Ft. In.*	*Ft. In.*	*Lbs. Oz.*	*Ft.*	*In.*	*In.*	*Sq. in.*
¾	.....	18 0	6 0	0 11	40,582	1.20	0.38	0.113
¼	.....	18 0	6 2½	1 6	30,109	1.65	.52	.21
	2	18 0	6 0	2 2	37,895	2.00	.625	.307
	.....	18 0	.....	2 3	31,268	2.15	.67	.352
	.....	18 0	6 0	2 3	35,383	2.07	.66	.342
	.....	18 3	6 0	3 13	30,637	2.85	.95	.709
	.....	18 0	6 0	3 14	27,871	2.85	.93	.679
	.....	18 0	6 0	3 12	24,960	2.85	.92	.665
	.....	17 10	6 0	4 0	26,304	2.90	.93	.679
⅞	.....	17 11½	6 0	3 11	24,106	2.85	.93	.68
1	.....	17 10½	6 0	5 0	31,460	3.20	1.04	.849
	3	17 6	6 0	5 8	24,818	3.45	1.12	.985
2	.....	18 ½	6 0	19 0	23,549	6.55	2.12	3.53
	6	17 9½	6 0	20 0	29,534	6.65	2.17	3.70
	6	18 0	6 0	20 0	33,930	7.05	2.39	4.49
	8	18 1	6 0	35 0	24,100	9.05	2.95	6.83

Nominal size.		Tensile strength.		Parted.
Diameter.	Circumference.	Load.	Stress (lb. per sq. in.).	
In.	*In.*	*Lbs.*		
¾	.....	1,550	13,717	1 strand 28 in. from end of splice.
¼	.....	2,300	10,952	1 strand at the middle of length.
	2	4,500	14,658	1 strand 3 in. from end of splice.
	.....	3,800	10,790	1 strand 10 in. from end of splice.
	.....	4,300	12,573	1 strand at middle.
	.....	6,400	9,027	1 strand 28 in. from end of splice.
	.....	6,000	8,835	1 strand 22 in. from end of splice.
	.....	5,200	7,819	1 strand 14 in. from end of splice.
	.....	5,900	8,689	1 strand 22 in. from end of splice.
	.....	6,600	9,705	1 strand 15 in. from end of splice.
1	.....	8,800	10,360	1 strand at the splice.
	3	7,800	7,918	Do.
2	.....	24,800	7,025	1 strand 12 in. from end of splice.
	6	33,200	8,972	Do.
	6	37,700	8,396	1 strand 18 in. from end of splice.
	8	46,900	6,860	Do.

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WIRE ROPE.

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Wire rope.

[Rope prepared for testing with closed sockets at the ends.]

Marks.	Nominal size, diameter.	Length between sockets.	Actual size, diameter.	Number of strands.	Number of wires per strand.
	In.	*Ft. in.*	*In.*		
Tiller rope	¼	5 9½	0.28	.....	.....
Hoisting rope	5/16	5 8	0.59	6	19
Crucible cast-steel hoisting rope	5/16	9 10	0.58	6	19
Galvanized	⅜	9 6	0.80	6	19
Crucible cast-steel hoisting rope	⅜	9 6	0.80	6	19
Plow steel	⅜	9 7½	0.95	8	19
Flexible plow steel	⅜	9 5½	0.92	8	19
Plow steel, extra flexible	⅜	14 4	0.95	8	19
Extra pliable	1	9 3	1.05	6	37
Do	1	9 4½	1.05	6	37

Marks.	Diameter of wire.	Core.	Breaking strength.	Parted.
	In.		*Lbs.*	
Tiller rope	.....	.....	4,200	5 strands, 21 inches from end of socket.
Hoisting rope	0.032–.043	Hemp...	26,500	4 strands at end of socket.
Crucible cast-steel hoisting rope.	0.0410	...do....	26,600	3 strands, 30 inches from end of socket.
Galvanized	0.05	...do....	43,600	1 strand, 27 inches from end of socket.
Crucible cast-steel hoisting rope.	.042–.058	...do....	38,200	3 strands, 36 inches from end of socket.
Plow steel	0.048	Sisal....	56,100	6 strands at end of socket.
Flexible plow steel	0.047	...do....	57,900	4 strands, 12 inches from end of socket.
Plow steel, extra flexible	0.048	Hemp...	59,400	5 strands, 6 feet from end of socket.
Extra pliable	0.048	...do....	85,600	3 strands at the middle.
Do	.045–.055	...do....	80,200	3 strands, 37 inches from end of socket.

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CHAIN.

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Chain.

Diameter of wire.	Number of links.	Outside length of links.	Outside width of links.	Tensile strength.	Manner of failure.
In.		*In.*	*In.*	*Lb.*	
0.27	7	1.34	0.89	7,650	Fractured first link of chain at the quarter.
0.42	7	2.02	1.37	16,932	Fractured the third link of chain at weld.
0.47	21	2.30	1.57	6,900	Fractured the fifth link of chain along weld at welded end.
0.47	16	2.30	1.57	7,800	Fractured the sixth link of chain along weld at welded end.
0.47	10	2.30	1.57	8,200	Fractured the second link of chain at the welded end.
0.49	7	2.44	1.60	15,900	Fractured the second link of chain at the weld.
0.53	13	2.47–2.34	1.80–1.72	16,200	Fractured the second link of chain at the quarter welded end.
0.63	12	3.00–2.74	2.12–2.04	23,600	Fractured the first link of chain at the quarter welded end.
1.64	3	7.25	5.45	166,400	Fractured the middle link at the quarter at welded end.

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RUBBER.

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Rubber.

Marks.	Thickness.	Width.	Sectional area.	Tensile strength.		Elongation in 2 inches.	
				Load.	Stress (lb. per sq. in.).	Inches.	Per cent.
	In.	*In.*	*Sq. in.*	*Lb.*			
Bead rubber	0.39	1.00	0.39	405	1,038	.....	.....
Covering rubber	0.44	0.98	0.43	215	500	2.20	110.0
Do	0.46	0.98	0.451	291	645	4.20	210.0
Do	0.48	1.00	0.48	295	614	3.85	192.5
Do	0.48	1.02	0.49	220	449	4.45	222.5
Do	0.48	0.96	0.46	268	582	5.15	257.5
Red foundation	0.48	0.99	0.475	453	953	5.35	267.5
Covering rubber	0.48	0.95	0.46	281	611	4.25	212.5
Do	0.49	0.98	0.48	202	420	1.70	85.0
Do	0.49	0.98	0.48	224	467	4.75	237.5
Do	0.50	0.98	0.49	298	608	4.05	202.5
Do	0.52	0.91	0.47	369	785	3.64	182.0
Do	0.54	1.01	0.54	469	868	3.95	197.5
Do	0.55	1.00	0.55	257	467	4.05	202.5
Do	0.58	1.00	0.58	481	829	5.50	275.0
Do	0.58	0.97	0.56	385	687	4.62	231.0

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BRASS AND BRONZE.

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Seamless drawn-brass tubing.

TENSILE TEST.

Length of sample over all.	Width.	Average Thickness.	Sectional area.	Tensile strength.		Elongation.
				Total.	Lbs. per sq. in.	
In. 22.00	*In.* 1.501	*In.* 0.282	*Sq. in.* 0.423	*Lbs.* 17,200	40,661	*Per cent.* 40.0

BENDING TEST.

The ends of the test pieces were bent cold through an angle of 180° around a diameter equal to twice the thickness of the pipe without showing signs of cracks or flaws.

Tobin bronze.

Dimensions.		Sectional area.	Tensile strength.		Elongation.		Appearance of fracture.
Thickness.	Width.		Total.	Lbs. per sq. in.			
In.	*In.*	*Sq. in.*	*Lbs.*		*Inches.*	*Per cent.*	
0.251	1.0	0.251	15,900	63,300	In 2 in., 0.63...	In 2 in., 31.5...	Uniform light yellow.
.315	1.015	.320	14,100	44,060	In 6 in., 0.94...	In 6 in., 15.6...	Light yellow.
.316	1	.316	19,000	60,100	In 4 in., 1.35...	In 4 in., 33.75..	Uniform light yellow.
.746	.998	.745	42,400	56,900	In 2 in., 0.64...	In 2 in., 32.0...	Do.
.751	1.001	.752	50,800	67,600	In 2 in., 0.72...	In 2 in., 36.0...	Do.
.751	1	.751	55,200	73,500	In 2 in., 0.51...	In 2 in., 25.5...	Light yellow.
.623	.999	.622	40,200	64,600	In 2 in., 0.67...	In 2 in., 33.6...	Uniform light yellow.

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HOSE.

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Pneumatic hose.

TUBE TEST.

Gauged length of 2 inches laid off on each sample; stretched to 6 inches for 10 minutes and strain removed.

Marks.	Width.	Length.	Permanent set.
	In.	*In.*	*In.*
7-ply ½-inch	1.00	6.00	0.64
Do	1.00	6.00	.35
7-ply ¾-inch	1.00	6.00	.62
Do	1.00	6.00	.24

FRICTION TEST.

Marks.	Unwound in 10 minutes.
	In.
7-ply ½-inch	2.85
Do	2.88
Do	2.30
Do	2.25
7-ply ¾-inch	2.90
Do	2.85
Do	1.45
Do	1.50

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GALVANIZED RINGS.

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TENSILE TEST OF GALVANIZED RINGS.

Inside diameter.	Diameter of wire.	Breaking strength.	Inside diameter.	Diameter of wire.	Breaking strength.
In.	*In.*	*Lb.*	*In.*	*In.*	*Lb.*
1.00	0.20	2,550	1.00	0.17	2,351
1.04	.17	893	1.02	.16	734
1.00	.17	1,336	1.02	.16	1,046
1.00	.18	1,476	1.00	.17	1,943
1.00	.17	1,842	.99	.17	1,239
1.00	.18	984	1.00	.17	1,204
1.00	.18	957	1.00	.17	989
1.00	.18	779	1.00	.17	2,071
1.00	.18	721	1.00	.17	1,295
1.00	.18	2,060	1.00	.18	2,570
1.02	.16	490	1.00	.18	694
1.00	.17	2,305	1.00	.17	620
1.00	.18	765	1.00	.19	492
1.00	.18	1,316			

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MISCELLANEOUS.

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TENSILE TEST OF A ROUND STEEL BAR FOR BOLT MATERIAL

Length of bar over all, 18.75 in.

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.	
			Load.	Stress (lb. per sq. in.).	Load.	Stress (lb. per sq. in.).
15 T ...	*In.* 0.818	*Sq. in.* 0.525	*Lb.* 27,600	52,570	*Lb.* 45,600	86,860

Elongation in 8 in.		Elongations in inch sections.								Diameter at fracture.	Contraction of area.
In.	*P. ct.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*P. ct.*
1.78	22.2	0.14	0.17	0.14	0.18	0.16	0.21	0.25	[1] 0.53	0.56	53.1

[1] Inch section in which fracture occurred.

Appearance of fracture, fine silky, cup shaped.

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METALLOGRAPHIC EXAMINATIONS.

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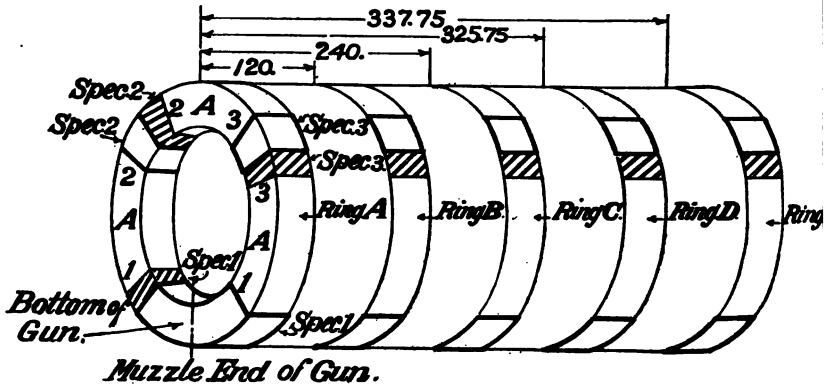

Specimens shown in heavy outline were prepared for Microscopic Examination.

Specimens shown by crosshatching were for Tension Specimens.

Fig. 1.

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TESTS OF TREPANNED RINGS FROM 12-INCH GUN.

Figure 1 shows the relative location of the rings in the gun and the distance of each from the muzzle. In laying off the specimens No. 1 was located at the bottom. This was done by selecting the portion showing the greatest wear, which was very marked near the breech and almost imperceptible at the muzzle. When the first cut was made in these rings the diameter was measured and compared with the original outside diameter.

Ring.	Diameter before cutting.	Diameter after cutting.	Difference.
	In.	*In.*	*In.*
A.....	12.983	12.842	0.141
B.....	12.981	12.822	.159
C.....	12.985	12.790	.195
D.....	12.980	12.704	.276
E.....	12.970	12.577	.393

In all cases the rings sprung together and the amount was much greater for the breech rings than the muzzle rings. The hardness of the various portions of these rings by the file, the Brinell machine, and the Shore scleroscope gave the following results:

Specimen.	Scleroscope.			File.			Brinell.	
	Land.	Groove.	Back.	Land.	Groove.	Back.	Groove.	Back.
A.....	33	27	31	H.	H.	S.	192	170
B.....	34	28	31	H.	H.	S.	166	156
C.....	38	33	31	H.	H.	S.	187	170
D.....	47	43	32	H.	H.	S.	187	149
E.....	48	48	30	H.	H.	S.	187	149

H—Hard. S—Soft.

The land is in each case harder than the groove for the scleroscope readings, although slightly softer near the muzzle. The fact that the groove near the muzzle is softer than the back for the scleroscope readings is believed to be due to the deposit of copper and powder residue. Effort was made to remove this, but it was found impossible to do so entirely.

Sections the width of each ring and of a length corresponding to about four grooves and five lands were cut from each ring for microscopical examination. Each specimen was prepared for examination by polishing (1) a part of the face opposite the land and grooves, (2) a face parallel to the axis of the gun and running through a land near the driving edge, (3) and a face normal to the axis. These sections are referred to as A, B, C, D, and E, beginning with the muzzle end and running back toward the firing chamber.

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The surface erosion was greatest in section E and diminished progressively toward the muzzle end, as shown in photograph No. 1. This photograph shows characteristically the appearance of each section. In section E there has been a very considerable flow of metal, and the cracks do not appear to be so numerous as in section D. In section D there are not only extensive transverse cracks, but also very extensive longitudinal cracks, the latter being particularly noticeable at the bases of the lands. In photograph No. 2, showing the faces normal to the axis, the cracks at the bases of the lands, i. e., the junction of the lands and grooves, are particularly evident in sections C and D. In section C there is no pronounced direction to the cracks, but the lands and the central portions of the grooves show a crackled appearance.

In section B the cracks are not so evident. There is some rounding of the lands, and the driving edge shows some cracks.

In section A the lands and grooves are clean-cut, with cracks only on the firing edge of the lands.

The depth of crack varies irregularly in each section and somewhat regularly in sections proceeding from A to E, increasing in depth toward the firing chamber. The number of cracks, however, does not vary in the same way. In section E, where the greatest erosion has taken place, the smallest number of cracks appear.

The greatest depth of crack appears in section D, in which measurement showed values as follows:

Inch.	Inch.
0.036	0.033
.051	.042
.030	.029

The width of these same cracks at the mouth of the crack varied from 0.015 to 0.001 in.; the width halfway back varied between 0.001 and 0.007 in. In section E the depth varies between 0.024 and 0.39 in. In section C the average depth of crack is only a trifle less than in D, but the width is not nearly so great as in D.

In section B the depth and width both diminish, and in A there are no cracks visible on the face normal to the axis. On the face parallel to the axis, cut along the driving edge, there are a number of fine cracks approximately 0.01 in. in depth. These cracks are sharp and clean, while in section D, where they are slightly deeper, they are considerably wider, due to erosion.

Sections B, C, D, and E show a hard layer of metal on the face cut normal to the axis. All sections show the hard layer on the face parallel to and along the driving edge. The depth of the layer on the face normal to the axis varies as follows:

	Inches.
A,	.....
B,	0.0004
C,	.0008
D,	.0013
E,	.0015

On the driving edge of section A there is just the beginning of a hardened layer which is about 0.0001 in. in thickness.

Photographs Nos. 3, 4, 5, 6, 7, and 8 show the hard layer with cracks breaking through. Photograph No. 3 shows the characteristic appearance of the driving edge of section A. The hard layer is not

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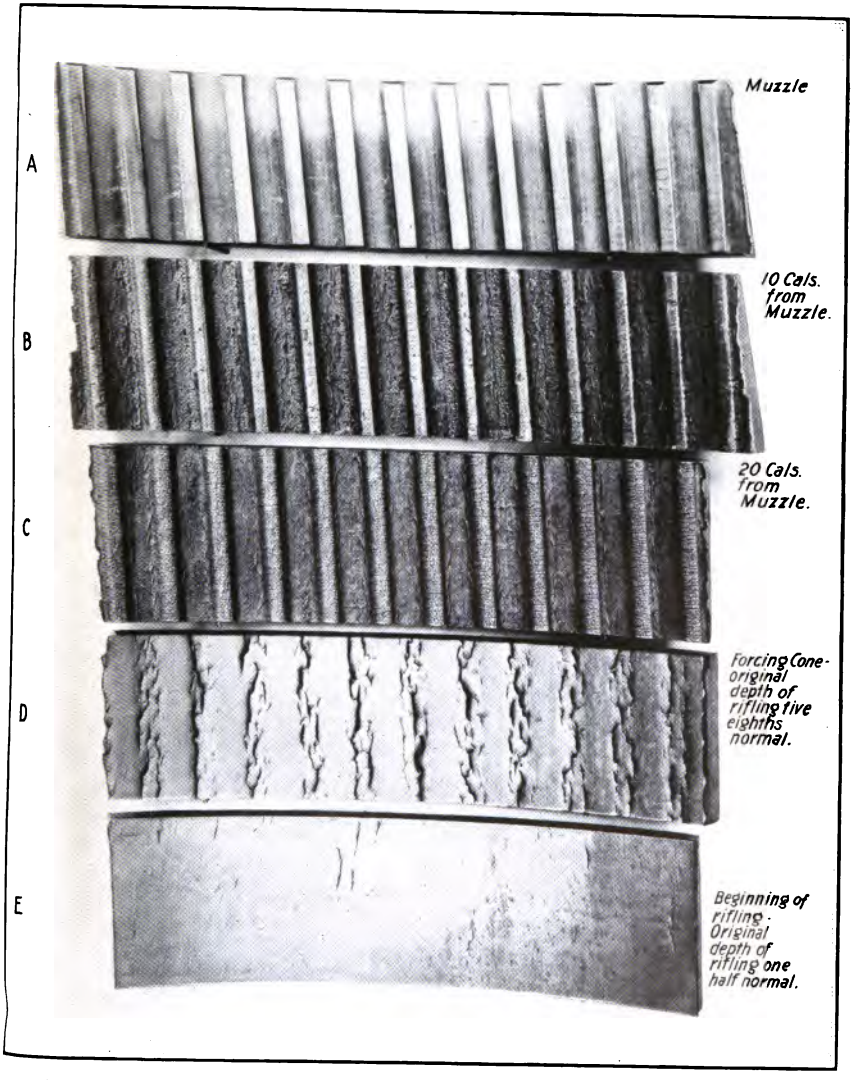

PHOTOGRAPH NO. 1.

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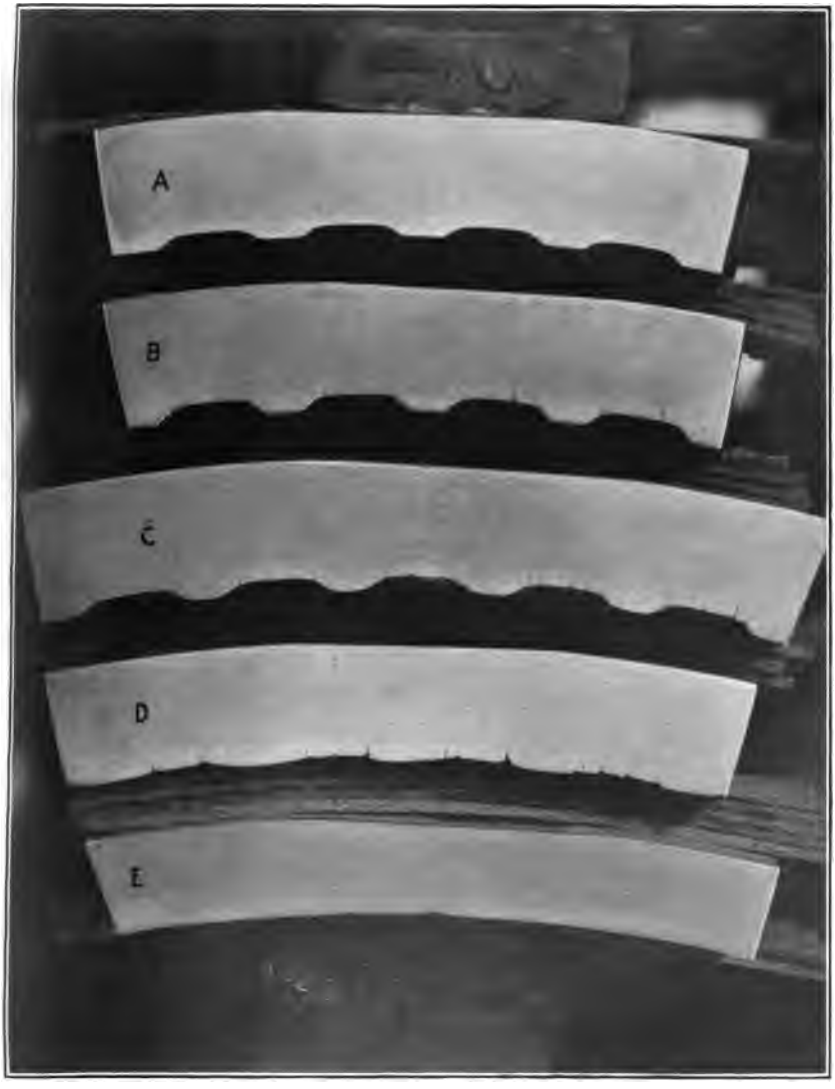

PHOTOGRAPH NO. 2.

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PHOTOGRAPH NO. 5. UNETCHED. SECTION D. X50.

PHOTOGRAPH NO. 3. ETCHED. SECTION A. X50.

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PHOTOGRAPH NO. 6. UNETCHED.
SECTION D. X50.

PHOTOGRAPH NO. 4. ETCHED.
SECTION C. X50.

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PHOTOGRAPH NO. 7. SECTION D. ETCHED. X100.

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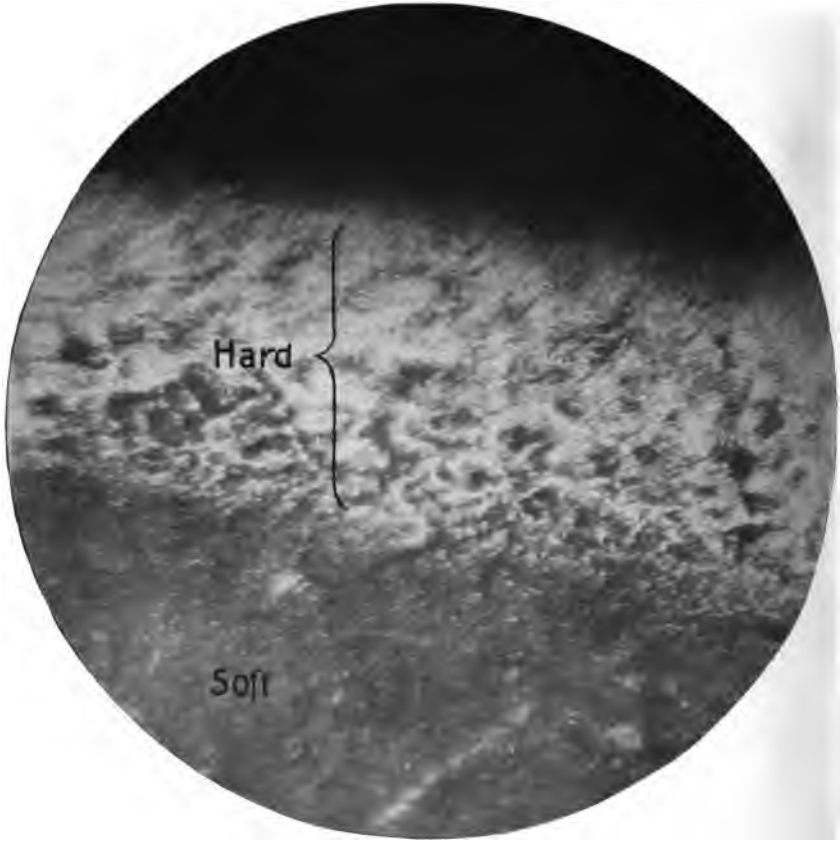

PHOTOGRAPH NO. 8. SECTION E. ETCHED. X100.

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visible, as it is quite impossible to have the extremely thin layer and the crack in focus at the same time. The metal has been etched, and shows a good sorbitic structure.

In photograph No. 4, taken from section C, is shown the etched structure, slightly abnormal, a crack, and a portion of the hard layer, which is marked in red ink.

In photographs Nos. 5 and 6, taken from section D, is seen more distinctly the hard layer, with its accompanying cracks. Both surfaces are unetched.

In photograph No. 7, magnified 100 diameters, is shown the hard layer and a crack developed at the junction of a land and groove. In etching the normal structure of the metal is developed very readily, while the structure of the hard layer is developed only with difficulty. Consequently, in this photograph the hard layer is shown as almost structureless. That the hard layer has a distinct structure of its own is shown in photograph No. 8, taken from section E.

Attempts were made to cut out portions of the hard layer for chemical analysis, but the efforts were unsuccessful. The metal was too hard to be taken from the rifled surface and the layer too thin to be taken from the rear. Conclusions can not be drawn, therefore, as to the amount of carbon contained in the hard layer.

To account for the hardening and cracking of the rifled surface, three theories seem plausible, and these will be discussed separately.

The surface may be hardened in a manner similar to the hardening of a tool steel, i. e., it may be heated by the combustion of the powder to a temperature above the critical temperature, say above 720° C., and the great mass of metal back of this thin layer would suffice to extract the heat so as to cool the steel so rapidly through the critical range that *hardness* of the layer which had reached a temperature above the critical range would result.

The steel so hardened would be brittle and without any plasticity, and the friction of the rushing projectile might easily produce a series of incipient cracks, which would in time develop in size and extent.

The evidence in favor of this view is not conclusive, and is rather against it than for it. There can be no doubt of the high temperature produced by the combustion of the powder, but the velocity of the explosive wave is so great that there would be only a brief interval through which the heat might be communicated to the metal. To raise the metal to the required temperature would require a number of rounds of firing, and the body of the tube being considerably heated, the process would really be a hardening followed by a tempering process giving a fairly soft metal. The surface is, however, glass hard wherever it is found. Definite evidence in regard to the temperature of the metal in various parts of the tube is lacking, and until further evidence is obtained no satisfactory conclusions can be drawn.

The microscopic structure of steel hardened by heating through the critical range and quenching is characteristic, but no such structure can be produced in this hard layer by any of the standard reagents commonly used for this purpose.

The second method by which hardness may be produced is by a process similar to wire-drawing and commonly referred to as "cold work." It is a well-known fact that even the most ductile of metals, such as gold, platinum, etc., will lose their plasticity and become hard

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and brittle when subjected to drawing, hammering, etc. In wire-drawing it becomes necessary to frequently anneal the metal in order to restore the plasticity, and thus prevent it from cracking or breaking. This phenomenon is common not only to the ductile metals, but is also a property of the more brittle metals, such as antimony, and of minerals, such as crystallized calcite, etc.

The mechanism of this action has been studied in detail by Beilby, and an interesting résumé of his work will be found in his presidential lecture on "The hard and soft states of metals," delivered in 1911 before the Institute of Metals. According to Beilby, a surface skin may be built up by mechanical movement, which gives unmistakable evidence that the surface must have passed through a state in which it must have possessed the perfect mobility of a liquid. This surface possesses distinctive properties which differentiate it from the substance beneath it. Hardening thus results from the formation at all the internal surfaces of slip or shear of mobile layers similar to those produced on the surface by mechanical movement. These layers only retain their mobility for a brief period, and then solidify in a vitreous, amorphous state, cementing together all of the surfaces of slip or shear throughout the mass.

Such a surface produced by polishing, burnishing, drawing, hammering, or cold work of any kind possesses the property of hardness and brittleness. This layer may be restored again to its natural state by annealing, which destroys the vitreous character of the layer and converts the metal again into its original crystalline, ductile state.

By the application of this idea to the rifling of a gun we have a simple explanation of the hardening and cracking of the surface. By the passage of the rotating band of the projectile over the rifled surface the surface of the steel is caused to flow in a mobile layer, and when solidification takes place it is in the vitreous or hard form. After the hard layer has passed a certain critical depth the mobility is no longer transmitted through it when force is applied by the moving projectile, and the only alternative is for cracks to result from this force.

The evidence seems almost conclusive that the hard layer and the cracks are produced by this process rather than by heat alone. The microscopical evidence also favors this view. In photograph No. 8, the hardened layer, etched with alcoholic nitric acid, is seen to be distinctly vitreous and not martensitic as would be the case were the layer produced by heating and quenching.

This theory also accounts for the fact that in section E, where there is undoubtedly the greatest amount of heat, there are the smallest number of cracks. At the higher temperature there is greater plasticity of the metal, and consequently there is greater opportunity for the cracks to fill up by flow of metal. The friction in this portion of the gun would necessarily be produced by the great rush of gases.

The third method by which hardness may be produced is by increasing the amount of carbon on the surface of the metal. This might well be caused by a cementation process from the gases produced in the combustion of the powder. This would necessitate a very high percentage of carbon. Inasmuch as the hard layer is so thin and so difficult to do anything with, no direct evidence has been obtained. This method would best account for the fact that the hard layer is thickest in the firing chamber.

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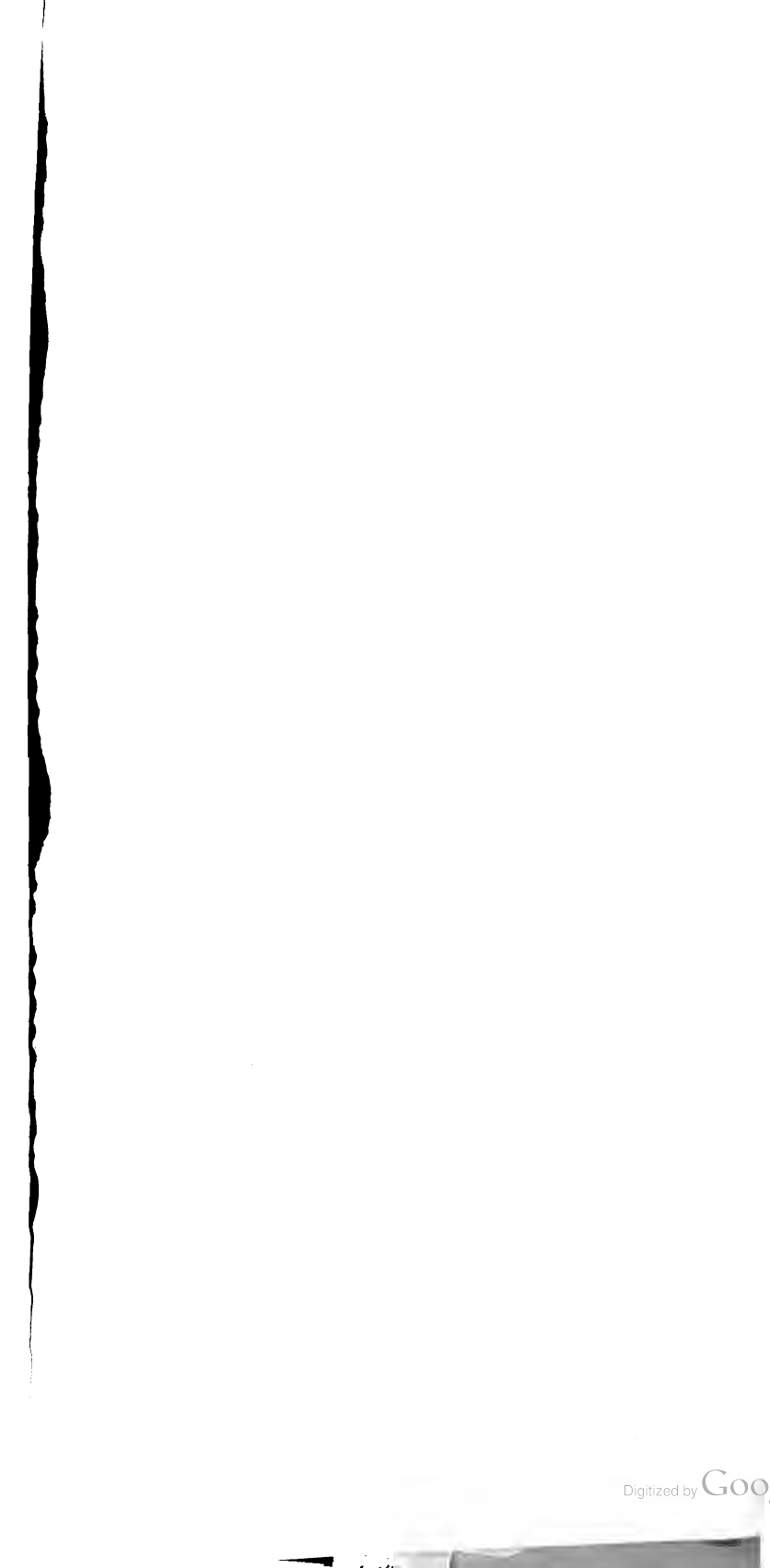

PHOTOGRAPH NO. 1. ORIGINAL AMORPHOUS STEEL. X50.

PHOTOGRAPH NO. 2. ORIGINAL SMALL ARM STEEL. X50.

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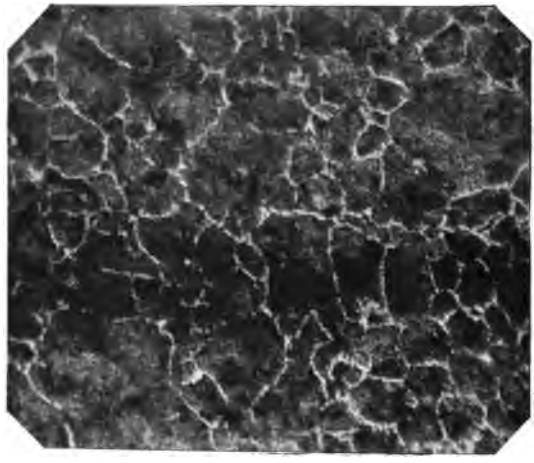

PHOTOGRAPH NO. 3. ORIGINAL NICKEL STEEL X50.

PHOTOGRAPH NO. 4. ORIGINAL GUN STEEL. X50.

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PHOTOGRAPH NO. 5. NICKEL STEEL FIRED. X50.

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MICROSCOPIC EXAMINATION OF A SERIES OF STEELS SUBJECTED TO EROSION TESTS AT SANDY HOOK.

1. Microscopic examination was made from each of the four original steels and photographs of each are herewith submitted.

Photograph No. 1 shows the structure of the steel marked "Amorphous." It is truly amorphous in structure and is troostitic in character, etching very darkly, showing only traces of the usual sorbitic structure.

Photograph No. 2 shows the structure of the small-arm steel. It shows a homogeneous mixture of troostite changing to sorbite, with some lighter appearing patches, which on further tempering would have changed into the darker etching material.

Photograph No. 3 shows the nickel-steel structure made up of sorbitic pearlite with excess ferrite. The grain is somewhat coarse, indicating a fairly unsatisfactory heat treatment.

Photograph No. 4 is made from the gun steel and shows a homogeneous sorbitic structure with only small amounts of free ferrite. The heat treatment has been satisfactory.

Considering the composition of each steel, the structures are about what one would expect by oil treating and tempering, with the possible exception of the nickel steel, which shows coarser granulation than is desirable.

2. Microscopic examination was made also of each of these steels after having been subjected to the erosion tests. Great changes in structure have taken place on the inner portion of the tubes. The greatest change has taken place in the nickel steel.

3. Each steel has developed a hardened inner layer, partially due to the flow of metal alone, but more particularly to the change in the form of carbon. There was also a development of heat cracks, the greatest development taking place where there has been the greatest change in the form of carbon.

4. The change of structure is best illustrated in the nickel steel. In photograph No. 5 is shown the structure of the inner edge of the nickel-steel tube. Three distinct structures are seen. On the firing side, into which a crack has developed, the structure is that characteristic of a completely hardened steel, and is known as martensite. At higher magnifications this appears as a mass of needle-like crystals interpenetrating each other at an angle of about 60°. In this area, which is 0.015 inch in width, all of the carbon is in the "hardening" carbon form.

Beyond the martensite is a uniform layer of troostite of approximately the same width. This layer is less hard, but somewhat harder than the original steel. In it the carbon has been partially transformed from the "hardening" into the "carbide" state. This is an intermediate transition stage between martensite and sorbite.

The third structure is that of sorbite similar to the original steel, but not showing the granulation of the original. The carbon has still further transformed into the "carbide" state. Had the carbon been completely transformed into "carbide" carbon, the structure would have been that of pearlite. Sorbite is, therefore, a transition form between troostite and pearlite.

Similar changes have taken place in the small-arm steel, only to a smaller extent, the respective widths of the martensite and troostite areas being, respectively, 0.004 and 0.006 inch.

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In the amorphous steel the martensite area is missing, but troostite approximately 0.005 inch in width, appears on the firing edge.

The gun steel showed a very thin area of troostite, approximately 0.003 inch in width.

5. The cause of the changes in structure and the corresponding changes of carbon form is due to the heating of the metal above the critical temperature, and the different rates of cooling from these temperatures. In order to form martensite, the steel must be heated to above the critical temperature and rapidly cooled. With more slow cooling troostite results.

6. A very important influencing factor is the position of the critical transformation point. It is a well-known fact that some elements raise this point, while others lower it. Among the elements which raise the critical temperature is chromium. Nickel and manganese both have a tendency to lower this point. Consequently in a nickel steel the chances of producing martensite at a given temperature are greater than in a steel where no nickel is found or where chromium occurs. In the nickel steel there is the combined influence of the 1.65 per cent of nickel and the rather high per cent (0.785) of manganese. With both of these elements tending to lower the critical temperature, the hard and brittle martensite is easily formed.

7. In the amorphous and small-arm steels there is the counteracting influence of chromium and nickel, the ratio of nickel to chromium being about the same, and the nickel exerting a greater influence than chromium, but there is the added influence of a larger amount of manganese in the small-arm steel. It would, therefore, be expected that the small-arm steel would more readily show martensite, as it does.

8. In the gun steel there is no nickel to influence the critical point, and only the manganese, which in a carbon steel is not much affected by the amount present.

9. These facts have no particular bearing upon the erosion losses in the various steels in this series of experiments, but they have a very decided bearing upon the development of heat cracks in similar steels. If the same tubes were to be subjected to a second series of tests, the presence of the hard, brittle martensite would undoubtedly have a greater influence toward producing heat cracks than the soft, ductile sorbite. Thus the nickel steel might be expected to show greater development of heat cracks and perhaps greater erosion than the gun steel.

10. These facts also have an important bearing on the theory of the development of heat cracks in general. It is believed by some that heat cracks are formed because of the formation of a hard surface layer, due to heating of a skin of the rifled surface to a temperature above the critical temperature, followed by the sudden cooling of the layer by the large body of metal back of it. If this were true, then such a gun in which heat cracks have developed should show the martensite structure. In the examination of a considerable number of such steels no evidence of martensite has ever been found. In fact, troostite is never found.

11. Therefore it is concluded that the development of heat cracks is due to the presence of a hard surface produced by cementation of the metal by the products of combustion of the powder and by work put upon the surface by the moving projectile.

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PHOTOGRAPH NO. 4. SPECIMEN 106.
GUN BODY. X50.

PHOTOGRAPH NO. 1. SPECIMEN 256-1.
JACKET X50.

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PHOTOGRAPH NO. 2. SPECIMEN 257-2. TUBE. X50.

PHOTOGRAPH NO. 3. SPECIMEN 257-2. TUBE. X50.

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TEST NO. 1302.

REPORT OF STEEL ANALYSIS, WATERTOWN ARSENAL.

Sample.	C.	Mn.	Si.	S.	P.	Ni.	Chromium.
Erosion test, 12T2 amorphous	0.320	0.252	0.152	0.018	0.017	2.25	1.62
Erosion test, 12T4 small-arm barrel	.507	.427	.203	.020	.027	1.77	1.23
Erosion test, 12 T6nickel steel, 3-inch R. F. G., 170	.500	.785	.256	.018	.020	1.65	.....
Erosion test, 12T8 gun steel A, hoop 5-inch gun	.553	.742	.235	.023	.047	.....	.....

BAR STOCK FOR SUBCALIBER GUNS.

The chemical analysis showed the following composition:

Marks.	C.	Mn.	Si.	S.	P.	Ni.
Tube 256–1	0.38	0.64	0.210	0.017	0.031	3.16
Jacket 256–1	.384	.62	.192	.020	.033	3.19
Tube 257–2	.390	.58	.188	.020	.035	3.15
Jacket 257–2	.380	.57	.232	.020	.033	3.17
H. B. L.	.39	.77	.178	.017	.020	3.36
Gun body No. 125	.40	.77	.11	.027	.015	1.35
Gun body No. 126	.39	.77	.11	.027	.016	1.35

The physical tests gave the following properties:

Marks.	Elastic limit.	Tensile. strength.	Elongation.	Contraction.
125 G. B	58,500	107,000	10.0	9.5
126 G. B	57,500	105.500	14.0	16.9

Seven specimens representing tube, jacket, and disk were polished and examined microscopically. The unetched specimens showed somewhat more than the average amount of inclosed slag, much of it being drawn through the material in lines in the direction of rolling.

The etched specimens show a variety of structures which show that the material is far from uniform. Some of the specimens show a very marked striated or banded appearance, others show small-sized streaks with slag inclosures, and some a very coarse grain. The material as a whole is heterogeneous in character, and on this account each piece would require its own particular heat treatment to produce the best results.

The banded or striated structure, consisting of alternate layers of ferrite and pearlite, is shown in photographs 1, 2, and 3, representing, respectively, specimens marked "256–1 jacket," "257–2 jacket," and "257–2 tube." Test pieces of such material, if cut radial or longitudinal, would show decidedly different tests even after the material had been subjected to heat treatment.

The lack of uniformity is further shown in photograph No. 4, which is taken from the edge of disk marked "126 gun body." It shows a

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granular structure with very decided slag streaks. Farther away from the edge the structure is decidedly coarse, as shown in photograph No. 5.

The bar stock from the 3.8-in. howitzer is represented by photograph No. 6, which was taken from specimen marked "H. B. L." This specimen has evidently been heat treated. It shows a uniform sorbitic structure

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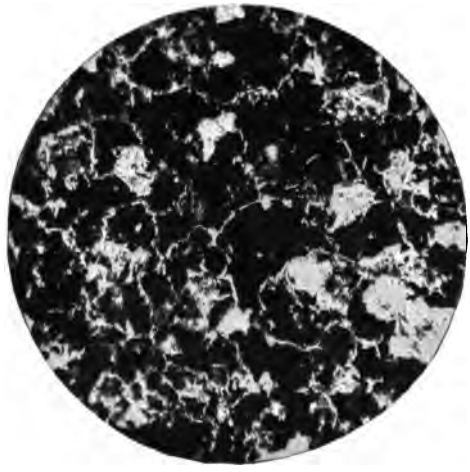
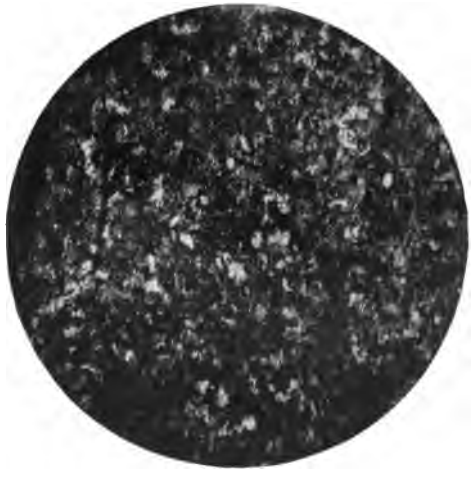


PHOTOGRAPH NO. 5. SPECIMEN 126. GUN BODY. X50.



PHOTOGRAPH NO. 6. SPECIMEN H. B. L. X50.

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PRIVATE TESTS.

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TESTS MADE FOR PRIVATE PARTIES DURING THE FISCAL YEAR ENDED JUNE 30, 1913.

Date.	Material.	Name.	City and State.
1912.			
July 9	Concrete cylinders	Boston Transit Commission	Boston, Mass.
24	Concrete building blocks	Columbia Concrete Co	West Somerville, Mass.
25	Steel	American & British Mfg. Co	Providence, R. I.
Aug. 5	Concrete cubes	Boston Elevated Ry. Co	Boston, Mass.
8	Concrete cylinders	Boston Transit Commission	Do.
10	Concrete building block	Gustavo Rappoli	East Boston, Mass.
12	Cast iron	Davis & Farnum Mfg. Co	Waltham, Mass.
14	Concrete cubes	Boston Elevated Ry. Co	Boston, Mass.
15	do	do	Do.
15	Steel	A. & J. M. Anderson Mfg. Co	South Boston, Mass.
19	do	H. H. Franklin Mfg. Co	Syracuse, N. Y.
21	Rubber belting	Revere Rubber Co	Chelsea, Mass.
28	Concrete building block	Gustavo Rappoli	East Boston, Mass.
28	Concrete cube	Boston Elevated Ry. Co	Boston, Mass.
29	Concrete building block	Thomas O'Malley	Clinton, Mass.
Sept. 4	Concrete cube	Boston Elevated Ry. Co	Boston, Mass.
10	do	do	Do.
11	Swedish iron	Dodge, Haley & Co	Do.
12	Concrete cubes	Boston Elevated Ry. Co	Do.
12	Concrete building block	Thomas Bayliss & Son	Everett, Mass.
12	Buoy shackles	Fletcher & Crowell Co	Portland, Me.
17	Concrete cylinders	Boston Transit Commission	Boston, Mass.
17	Sash chain	The Bridgeport Chain Co	Bridgeport, Conn.
18	Concrete cube	Boston Elevated Ry. Co	Boston, Mass.
24	do	do	Do.
Oct. 4	do	do	Do.
8	Concrete cylinders	Boston Transit Commission	Do.
9	Concrete cubes	Boston Elevated Ry. Co	Do.
15	Welded channel	Board of Water Supply	New York, N. Y.
18	Rubber belting	Revere Rubber Co	Chelsea, Mass.
18	Buoy shackles	Fletcher & Crowell Co	Portland, Me.
19	Bronze	The Portland Co	Do.
21	Columns	W. C. Whittredge & Co	Lynn, Mass.
21	Concrete cubes	Boston Elevated Ry. Co	Boston, Mass.
29	Welded channel	Board of Water Supply	New York, N. Y.
30	Concrete cylinders	Boston Transit Commission	Boston, Mass.
30	Gun-barrel steel	The Marlin Firearms Co	New Haven, Conn.
Nov. 5	Concrete cubes	Boston Elevated Ry. Co	Boston, Mass.
6	Hose coupling	Andrew J. Morse & Son (Inc.)	Do.
11	Steel	Erie Forge Co	Erie, Pa.
14	Concrete cubes	Boston Elevated Ry. Co	Boston, Mass.
16	Manila rope	Tucker & Carter Rope Co	New York, N. Y.
25	Concrete cube	Boston Elevated Ry. Co	Boston, Mass.
25	Tiles	Ernest S. Yates	Do.
Dec. 3	Draft gears	Standard Coupler Co	New York, N. Y.
4	Stone cubes	The North Carolina Granite Corporation.	Mt. Airy, N. C.
5	Concrete cylinders	Boston Transit Commission	Boston, Mass.
6	Columns	Louis Miller Co	East Boston, Mass.
17	Cast-iron shelf supports	The Snead & Co. Iron Works	Jersey City, N. J.
26	Concrete blocks	C. E. Lindsley Co	Irvington, N. J.
1913.			
Jan. 3	Concrete slabs	Warren Bros. Laboratory	East Cambridge, Mass.
10	Concrete cylinders	Boston Transit Commission	Boston, Mass.
15	Concrete building blocks	Thomas Allen	Somerville, Mass.
29	Columns	Boston Bolt & Iron Co	Boston, Mass.
30	Steel	Gulick-Henderson Co	Pittsburgh, Pa.
Feb. 13	Concrete cylinders	Boston Transit Commission	Boston, Mass.
15	Steel	Detrick & Harvey Machine Co	Baltimore, Md.
19	Column	Daniel Buckley	Dorchester, Mass.
19	Cast iron	Progress Mfg. Co	Boston, Mass.
24	Concrete building block	James S. Foley	North Cambridge, Mass.
Mar. 3	Welds	The Royer Wheel Co	Aurora, Ind.
6	Buoy shackles	Fletcher & Crowell Co	Portland, Me.
10	Concrete cubes	Georgia Railway & Power Co	New York, N. Y.
17	Steel	H. H. Franklin Mfg. Co	Syracuse, N. Y.
19	Concrete cubes	Dalton Power Co	Fitzdale, Vt.
19	Concrete building blocks	Theo. Kaltanowski	Buffalo, N. Y.
20	Granite cube	French Creek Granite Co	St. Peters, Pa.

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Tests made for private parties during the fiscal year ended June 30, 1913—Continued.

Date.	Material.	Name.	City and State.
1913.			
Mar. 24	Welded channel	Board of Water Supply	New York, N. Y.
26	Malleable iron	The Laconia Car Co. Works	Laconia, N. H.
26	Steel	Prof. Albert Sauveur	Cambridge, Mass.
27	Concrete brick	Massachusetts Unit Brick & Tile Co	Boston, Mass.
29	Buoy shackles	Fletcher & Crowell Co	Portland, Me.
Apr. 1	Concrete cubes	Boston Elevated Ry. Co	Boston, Mass.
4	Steel	John A. Roebling's Sons Co	Trenton, N. J.
8	Welded channel	Board of Water Supply	New York, N. Y.
12	Steel	Prof. Albert Sauveur	Cambridge, Mass.
21	Concrete cubes	Boston Elevated Ry. Co	Boston, Mass.
21	Links	Thomas Laughlin Co	Portland, Me.
23	Iron	The Laconia Car Co. Works	Laconia, N. H.
24	do	do	Do.
24	Steel	Prof. Albert Sauveur	Cambridge, Mass.
24	Linen rope	Tucker & Carter Rope Co	New York, N. Y.
May 1	Steel	Midvale Steel Co	Philadelphia, Pa.
2	Concrete building blocks	John Haeusser	Buffalo, N. Y.
2	Steel	Prof. Albert Sauveur	Cambridge, Mass.
5	Concrete cube	Boston Elevated Ry. Co	Boston, Mass.
6	Cast iron	Davis & Farnum Mfg. Co	Waltham, Mass.
7	Wrought iron	B. M. Jones & Co. (Inc.)	Boston, Mass.
8	Chain	The Bridgeport Chain Co	Bridgeport, Conn.
9	Steel wire rope	North Packing & Provision Co	Boston, Mass.
10	Concrete slabs	Warren Bros. Laboratory	East Cambridge, Mass.
10	Steel	Carpenter Steel Co	Reading, Pa.
12	Iron	The Laconia Car Co. Works	Laconia, N. H.
12	Concrete building blocks	Theo. Kaitanowski	Buffalo, N. Y.
13	Concrete brick and building block.	E. J. Mulvihill	Waltham, Mass.
16	Buoy shackles	Fletcher & Crowell	Portland, Me.
17	Chain	Bridgeport Chain Co	Bridgeport, Conn.
17	Cast iron	Davis & Farnum Mfg. Co	Waltham, Mass.
26	Malleable iron	The Laconia Car. Co. Works	Laconia, N. H.
29	Cast iron	Davis & Farnum Mfg. Co	Waltham, Mass.
31	Concrete building blocks	S. R. Shultz	Buffalo, N. Y.
June 2	Concrete cube	Boston Elevated Ry. Co	Boston, Mass.
2	Concrete building bricks	Z. A. Houle	Dracut, Mass.
2	Steel	Prof. Albert Sauveur	Cambridge, Mass.
5	Rope	Columbian Rope Co	Boston, Mass.
9	Swivel	Fletcher & Crowell Co	Portland, Me.
11	Malleable iron	The Laconia Car Co. Works	Laconia, N. H.
12	Building tile	Ernest S. Yates	Boston, Mass.
16	Steel	Midvale Steel Co	Philadelphia, Pa.
24	Fiber	Geo. D. Burton	Boston, Mass.

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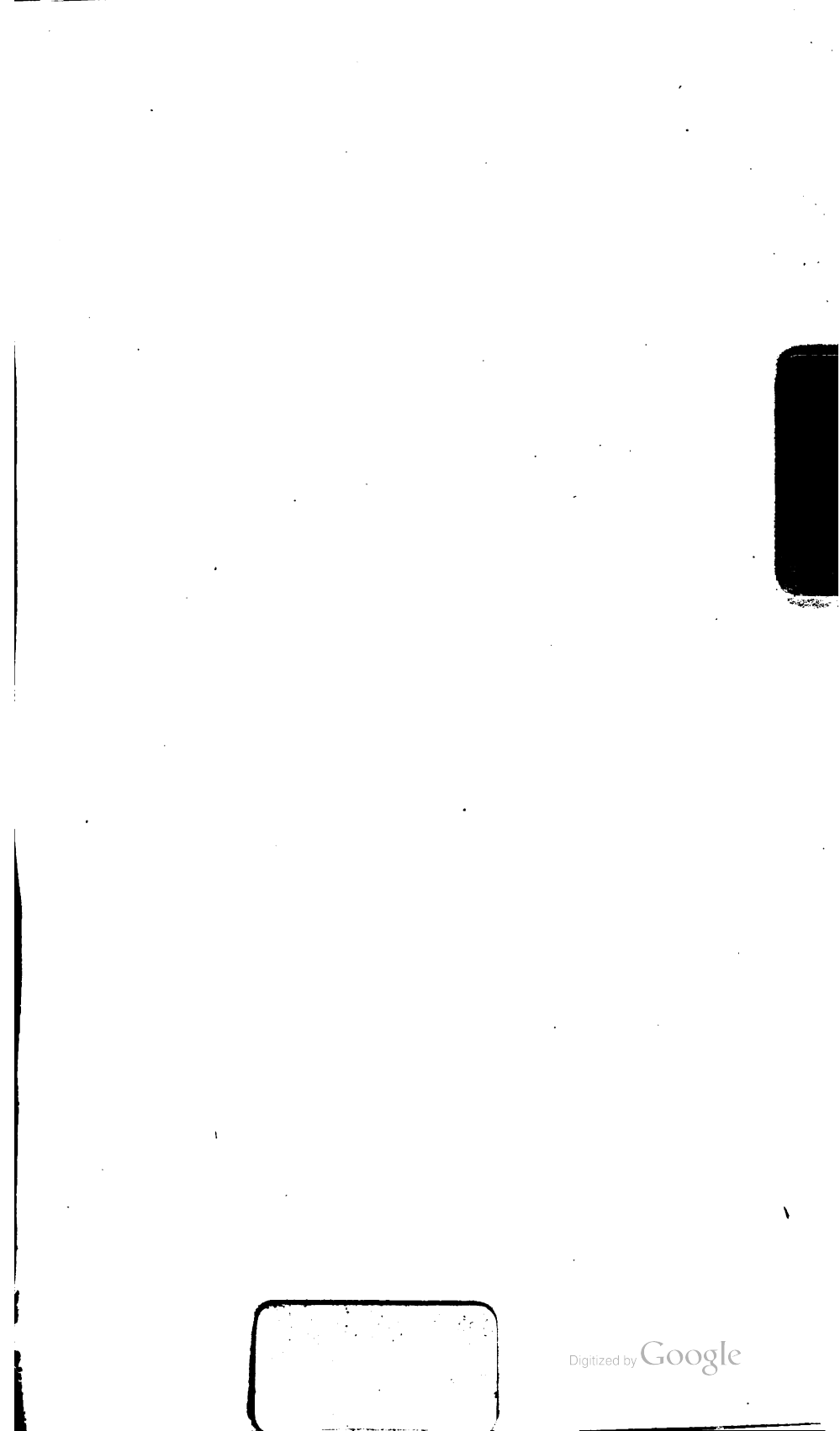
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